MCDONNELL DOUGLAS

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SPACE STATION PROGRAM (MODULAR)
COST ESTIMATES DOCUMENT
VOLUME I
Program Estimates

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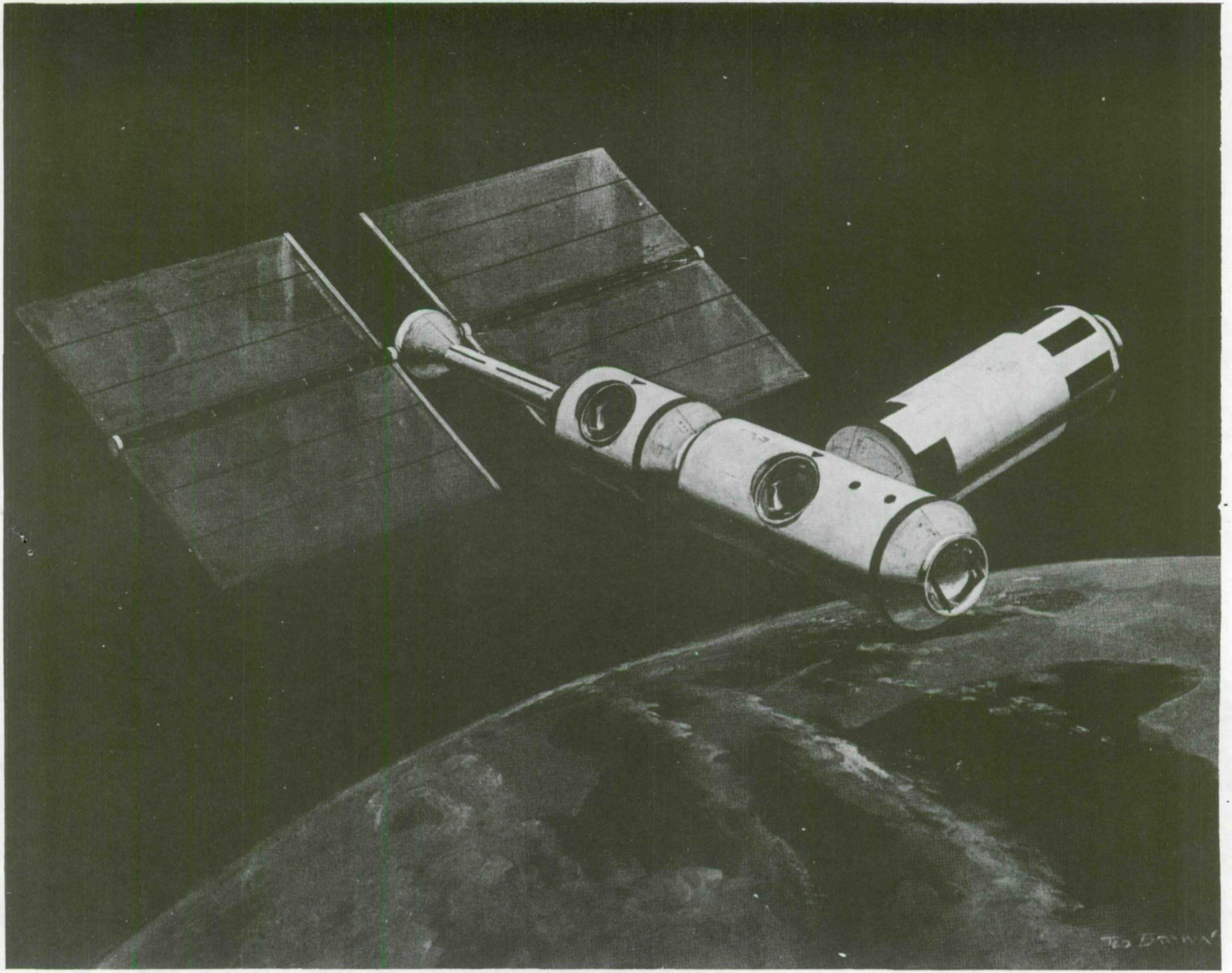

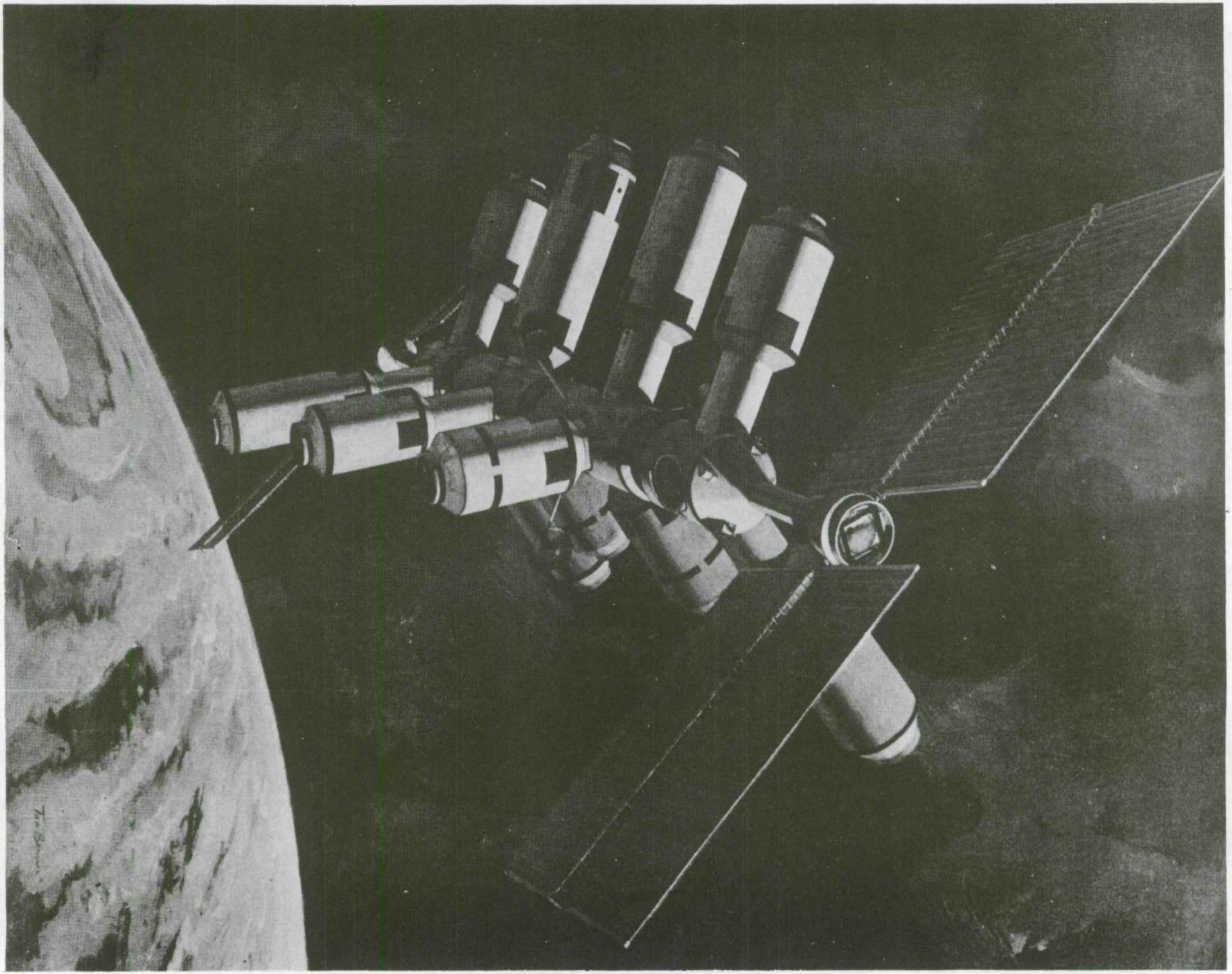

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PREFACE

Work reported herein was performed under the Space Station Phase B Extension Period Study (Contract NAS8-25140). The purpose of the Space Station Extension Period has been to perform the Phase B definition of the Modular Space Station. The modular program selected during the option period (low initial cost, incremental manning) was evaluated, requirements defined, and program definition and design accomplished to the depth necessary for exit from Phase B. The initial 2-1/2 months effort of the extension period was for analyses of the requirements associated with Modular Space Station program options. During this period, a baseline incrementally manned program has been derived with attendant experiment program options. In addition, those features of the program that significantly affect the initial development and early operating costs were identified, and their impact on the program were assessed. This assessment, together with a recommended program, were submitted for NASA review and approval on 15 April 1971. The second phase of the study (15 April to 3 December 1971) consists of the program definition and preliminary design of the approved Modular Space Station configuration.

This report is submitted as part of DRL No. MF-01, "Space Station Program (Modular) Cost Estimates Document" which consists of the following volumes:

Volume I—Program Estimates
Volume II—Subsystem Estimates

Volume I, Program Estimates, contains the program, project, and system level cost and schedule data.

Volume II, Subsystem Estimates, contains the subsystem cost and schedule data as well as the appendices (WBS Task Descriptions and Cost Estimate Data Form A).

DATA REQUIREMENTS (DR's) MSFC-DPD-235/DR NOs.
(Contract NAS8-25140)

Category	Designation	DR Number	Title
Configuration Management	CM	CM-01	Space Station Program (Modular) Specification
		CM-02	Space Station Project (Modular) Specification
		CM-03	Modular Space Station Project Part 1 CEI Specification
		CM-04	Interface and Support Requirements Document
Program Management	MA	MA-01	Space Stations Phase B Extension Study Plan
		MA-02	Performance Review Documentation
		MA-03	Letter Progress and Status Report
		MA-04	Executive Summary Report
		MA-05	Phase C/D Program Development Plan
		MA-06	Program Option Summary Report
Manning and Financial	MF	MF-01	Space Station Program (Modular) Cost Estimates Document
		MF-02	Financial Management Report
Mission Operations	MP	MP-01	Space Station Program (Modular) Mission Analysis Document
		MP-02	Space Station Program (Modular) Crew Operations Document
		MP-03	Integrated Mission Management Operations Document
System Engineering and Technical Description	SE	SE-01	Modular Space Station Concept
		SE-02	Information Management System Study Results Documentation
		SE-03	Technical Summary
		SE-04	Modular Space Station Detailed Preliminary Design
		SE-06	Crew/Cargo Module Definition Document
		SE-07	Modular Space Station Mass Properties Document
		SE-08	User's Handbook
		SE-10	Supporting Research and Technology Document
		SE-11	Alternate Bay sizes

SUBJECT REFERENCE MATRIX

LEGEND:
- CM Configuration Management
- MA Program Management
- MF Manning and Financial
- MP Mission Operations
- SE System Engineering and Technical Description

	CM				MA		MF	MP			SE								
	CM-01 Space Station Program (Modular) Specification	**CM-02** Space Station Project (Modular) Specification	**CM-03** Modular Space Station Project Part I CEI Spec	**CM-04** Interface and Support Requirement Document	**MA-05** Phase C/D Program Development Plan	**MA-06** Program Option Summary Report	**MF-01** Space Station Program (Modular) Cost Estimates Document	**MP-01** Space Station Program (Modular) Mission Analysis Document	**MP-02** Space Station Program (Modular) Crew Operations Document	**MP-03** Integrated Mission Management Operations Document	**SE-01** Modular Space Station Concept	**SE-02** Information Management System Study Results	**SE-03** Technical Summary	**SE-04** Modular SS Detailed Preliminary Design	**SE-06** Crew/Cargo Module Definition Document	**SE-07** Modular Space Station Mass Properties Document	**SE-08** User's Handbook	**SE-10** Supporting Research and Technology	**SE-11** Alternate Bay Sizes
2.0 Contractor Tasks																			
2.1 Develop Study Plan and Review Past Effort (MA-01)																			
2.2 Space Station Program (Modular) Mission Analysis								●											
2.3 Modular Space Station Configuration and Subsystems Definition														●					
2.4 Technical and Cost Tradeoff Studies							●												
2.4.4 Modular Space Station Option Summary											●								
2.5 Modular Space Station Detailed Preliminary Design														●					
Mass Properties																●			
2.6 Crew Operational Analysis									●										
2.7 Crew Cargo Module															●				
Mass Properties																●			
2.8 Integrated Mission Management Operations										●									
2.9 Hardware Commonality Assessment													●						
2.10 Program Support					●														
2.11 Requirements Definition																			
Space Station Program (Modular)	●																		
Space Station Project (Modular)		●																	
Modular Space Station Project–Part 1 CEI			●																
Interface and Support Requirements				●															
2.12 Plans					●														
2.13 Costs and Schedules							●												
2.14 Special Emphasis Task Information Management (IMS)												●							
Modular Space Station Mass Properties																●			
User's Handbook																	●		
Supporting Research and Technology																		●	
Technical Summary													●						
MOD 29																			●
MOD 40						●													

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Section 1
INTRODUCTION

1.1 BACKGROUND

With the advent of the Space Shuttle in the late 1970's, a long-term manned scientific laboratory in Earth orbit will become feasible. Using the shuttle for orbital buildup, logistics delivery, and return of scientific data, this laboratory will provide many advantages to the scientific community and will make available to the United States a platform for application to the solution of national problems such as ecology research, weather observation and prediction, and research in medicine and the life sciences. It will be ideally situated for Earth and space observation, and its location above the atmosphere will be of great benefit to the field of astronomy.

This orbiting laboratory can take many forms and can be configured to house a crew of up to 12 men. The initial study of the 33-foot-diameter Space Station, launched by the Saturn INT-21 and supporting a complement of 12, has been completed to a Phase B level and documented in the DRL-160 series. Recently completed studies are centered around a Space Station comprised of smaller, shuttle-launched modules. These modules could ultimately be configured to provide for a crew of the same size as on the 33-foot-diameter Space Station—but buildup would be gradual, beginning with a small initial crew and progressing toward greater capability by adding modules and crewmen on a flexible schedule.

The Modular Space Station Phase A—level study results are documented in the DRL-231 series. Recent Modular Space Station Phase B study results are documented in the DPD-235 series, of which this is a volume.

The Space Station will provide laboratory areas which, like similar facilities on Earth, will be designed for flexible, efficient changeover as research and

experimental programs proceed. Provisions will be included for such functions as data processing and evaluation, astronomy support, and test and calibration of optics. Zero gravity, which is desirable for the conduct of experiments, will be the normal mode of operation. In addition to experiments carried out within the station, the laboratories will support operation of experiments in separate modules that are either docked to the Space Station or free-flying.

Following launch and activation, Space Station operations will be largely autonomous, and an extensive ground support complex will be unnecessary. Ground activities will ordinarily be limited to long-range planning, control of logistics, and support of the experiment program.

The Initial Space Station (ISS) will be delivered to orbit by three Space Shuttle launches and will be assembled in space. A crew in the Shuttle orbiter will accompany the modules to assemble them and check interfacing functions.

ISS resupply and crew rotation will be carried out via round-trip Shuttle flights using Logistics Modules (Log M's) for transport and on-orbit storage of cargo. Of the four Log M's required, one will remain on orbit at all times.

Experiment modules will be delivered to the Space Station by the Shuttle as required by the experiment program. On return flights, the Shuttle will transport data from the experiment program, returning crewmen, and wastes.

The ISS configuration rendering is shown in the frontispiece. The Power/Subsystems Module will be launched first, followed at 30-day intervals by the Crew/Operations Module and the General Purpose Laboratory (GPL) Module. This configuration will provide for a crew of six. Subsequently, two additional modules (duplicate Crew/Operations and Power/Subsystems Modules) will be mated to the ISS to form the Growth Space Station (GSS) (shown in the frontispiece), which will house a crew of 12 and provide a

capability equivalent to the 33-foot INT-21-launched Space Station. GSS logistics support will use a Crew Cargo Module capable of transporting a crew of six.

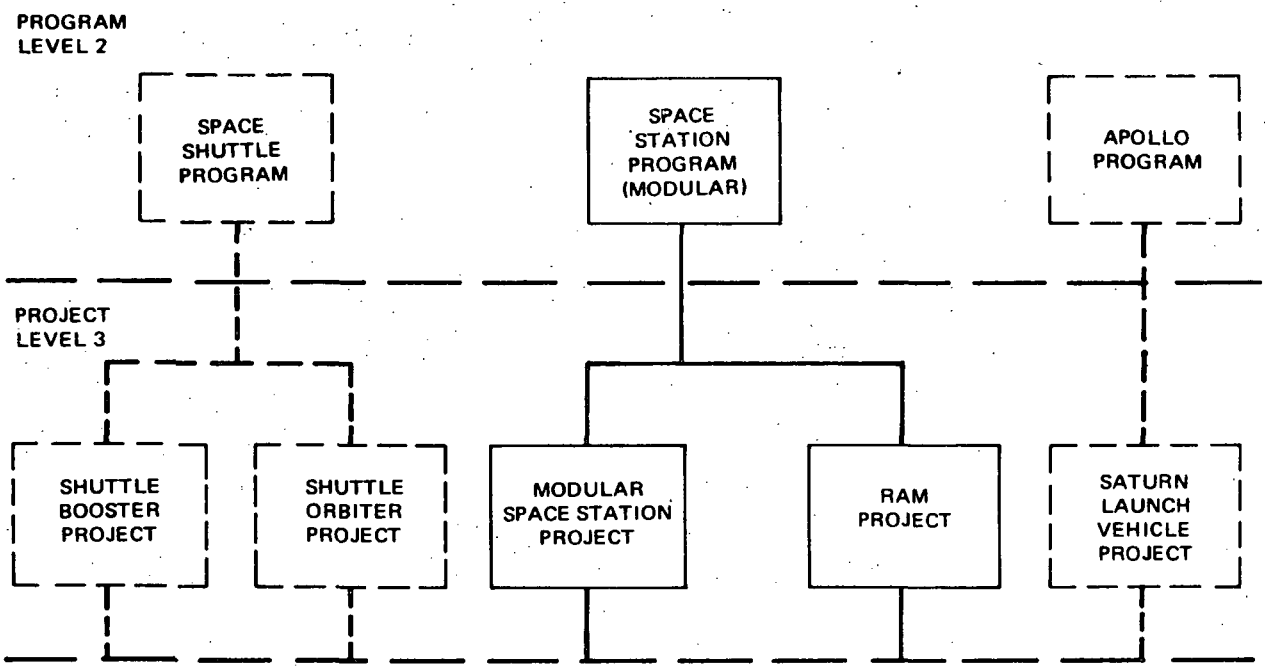
During ISS operations, five Research Applications Modules (RAM's) will be assembled to the Space Station. Three of these will be returned prior to completion of the GSS. In the GSS configuration, 12 additional RAM's will augment the two remaining from the ISS phase. Three of the RAM's delivered to the GSS will be free-flying modules.

During the baseline 10-year program, the Space Station will be serviced by Shuttle-supported Logistics Module or Crew Cargo Module flights.

1.2 SCOPE OF THIS VOLUME

The program and subsystem cost estimates and schedules in these volumes have been prepared in accordance with the Modular Space Station Program Definition (Phase B) Statement of Work, which calls for costs and schedules to be prepared for the Modular Space Station Program beginning with Phase C and D implementation and continuing through the flight operations phase of the program. All data were to be prepared at the appropriate levels and were to be consistent with the Work Breakdown Structure (WBS) (see Figure 1-1).

The level of definition varied for the different elements and phases of the program; therefore, the costs and schedules data varied as well. The costs and schedules of all elements and phases were reported at the project Level 3 and summarized to the program Level 2. The Space Station Project (ISS phase, first 5 years of operation) was reported to the system Level 4 and the (ISS) Space Station Modules system was reported to the subsystems Level 5 as indicated in the following Space Station Project (ISS only) WBS breakdown (see Figure 1-2).



- SPACE STATION MODULES
  - POWER/SUBSYSTEMS
  - CREW/OPERATIONS
  - GPL
  - SYSTEM INTEGRATION
- LOGISTICS MODULE (ISS ONLY)
- CREW CARGO MODULE (GSS ONLY)
- INTEGRAL EXPERIMENTS
- EXPERIMENT INTEGRATION
- GROUND SUPPORT EQUIPMENT
  - SPACE STATION MODULES
  - LOGISTICS MODULE
  - CREW CARGO MODULE
  - INTEGRAL EXPERIMENT
  - TEST ARTICLE
  - LAUNCH OPERATIONS
  - FLIGHT OPERATIONS
- TEST ARTICLES
- LAUNCH OPERATIONS
- FLIGHT OPERATIONS
- FACILITIES
- PROJECT MANAGEMENT
- SYSTEM SUPPORT

- ATTACHED MODULES
- FREE-FLYING MODULES
- EXPERIMENT "N"
- EXPERIMENT INTEGRATION
- GROUND SUPPORT EQUIPMENT
  - ATTACHED MODULES
  - FREE-FLYING MODULES
  - EXPERIMENT "N"
  - TEST ARTICLE
  - LAUNCH OPERATIONS
  - FLIGHT OPERATIONS
- TEST ARTICLES
- LAUNCH OPERATIONS
- FLIGHT OPERATIONS
- FACILITIES
- PROJECT MANAGEMENT
- SYSTEM SUPPORT

Figure 1-1. WBS for Space Station Program

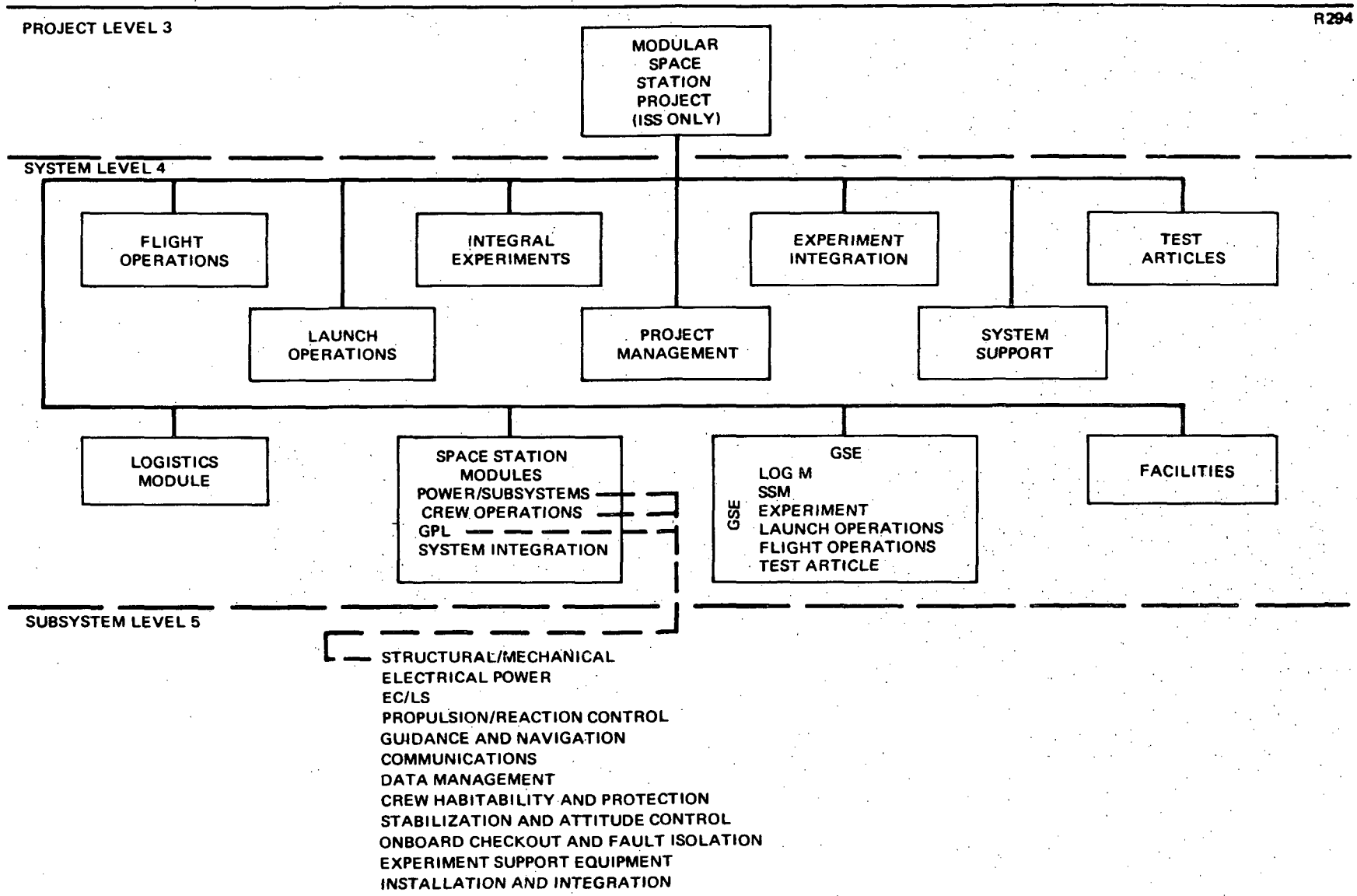


Figure 1-2. WBS for Space Station Project (ISS Phase)

Section 2

PROGRAM - LEVEL 2

2.1 SPACE STATION PROGRAM (ISS + GSS)

2.1.1 Summary

The 10-year Modular Space Station Program consists of three project level items: the Modular Space Station Project, the Research and Applications Modules (RAM) Project, and the Shuttle Operations, and two phases: the Initial Space Station (ISS) phase and the Growth Space Station (GSS) phase.

The ISS phase is used to describe the first 5 years of operations and the necessary design, development, test and evaluation (DDT&E) to achieve that capability. The ISS phase includes experiments, the Space Station Project and the RAM Project as they exist during this period of time. The (ISS) Space Station Project elements have been defined to the greatest depth; therefore, the majority of the cost and schedule data submitted are in this area.

The GSS phase is used to describe the second 5 years of operations and the necessary additional DDT&E to achieve that capability. The majority of the GSS phase DDT&E effort occurs in the same time period as the ISS operations (see Modular Space Station Program Schedule, Section 2.1.4).

The Space Station Project includes the following flight systems as well as related GSE, facilities, test articles, launch and flight operations, management and support tasks.

- Space Station Modules
  (ISS phase - power/subsystems No. 1, crew/operations No. 1, GPL)
  (GSS phase - power/subsystems No. 2, crew/operations No. 2)
- Integral experiments
- Logistic modules (ISS only)
- Crew cargo modules (GSS only)

The Space Station Project provides the modules which will make up the basic Space Station facility and will contain the living quarters for the crew, the power supply, life support systems, integral experiments, general purpose laboratory, and experiment provisions as well as RAM accommodations. The Space Station Project will also provide the Logistic Modules during the ISS phase which will accommodate cargo during transportation to and from orbit and provide orbital storage while attached to the station. During the GSS phase two logistic modules will be converted to crew cargo modules and two new crew cargo modules will be provided.

As indicated above, during the ISS phase three modules are joined on orbit to provide a six-man capability. Five years later the GSS 12-man capability is achieved by adding two modules to the original cluster of three.

The RAM project will provide specialized attached and free-flying modules and their associated experiments. The RAM modules and their missions will be capable of being supported by the Space Station. RAM and Space Station design and operation philosophy provide for maximum commonality to minimize development costs.

The Space Shuttle system will be the primary method of transportating Space Station modules, RAM modules, and logistic or crew cargo modules to and from low earth orbit, and will serve as a tug in the assembly and operation of the Space Station. The Space Shuttle operations include the launch and flight operations costs for all flights in support of the Space Station and RAM projects.

The tasks of the Space Station Program comprise all the effort defined in the lower level Work Breakdown Structure (WBS) elements of these three projects, as detailed in Appendix A, for the Initial Space Station (ISS) and the Growth Space Station (GSS), and for all phases of the program from DDT&E through Production and Operations. NASA effort for Program Management and System Support has been excluded by NASA direction.

Budgetary cost data generally are required early in the planning phases of a program to permit economic tradeoffs that affect system selection, to assess

fiscal practicality and time-phasing in relation to available resources, and to assist evaluations of long-range plans that define the course of the national space program. The Space Station Program cost estimates fulfill the NASA requirements for credibility, consistency, traceability, and documentation. The cost estimates correlate specification requirements, schedules, and costs in a meaningful manner.

This section presents an overview of the Space Station Program cost and funding implications. The budgetary cost estimates have been developed in consonance with the WBS, the available program definitions, and the cost assumptions, ground rules, and rationale as stated in Subsection 2. 1. 2.

The total cost of the Space Station Program has been estimated to be $6,486 million. As shown in Table 2-1, this total cost includes $3,548 million for DDT&E, $943 million for Production, and $1,995 million for Operations.

Table 2-1
MODULAR SPACE STATION PROGRAM SUMMARY

(1972 Dollars in Millions)

WBS	Title	DDTE	Production	Operations	Total	Percent
1X200	Modular Space Station Project	1,693	692	1,207	3,592	56
1X300	RAM Project	1,855	251	275	2,381	36
1X800	Space Shuttle Operations	-0-	-0-	513	513	8
Total Program		3,548	943	1,995	6,486	100
Percent		55	14	31	100	

Table 2-1 also indicates that the Modular Space Station Project, including integral experiments, represents 56 percent of the total program cost, while the RAM Project accounts for 36 percent of the total and the Space Shuttle Operations are the remaining 8 percent.

The DDT&E Phase, at $3,548 million, is 55 percent of total program cost, the Production Phase is 14 percent of the total, and Operations are 31 percent of the total.

The estimated total Space Station Program cost has been allocated in consonance with the WBS and the schedules presented in this volume. Figure 2-1 is a preliminary funding allocation by Government Fiscal Year and reflects the schedule influences which contribute to a peak loading of approximately $865 million in GFY 1984.

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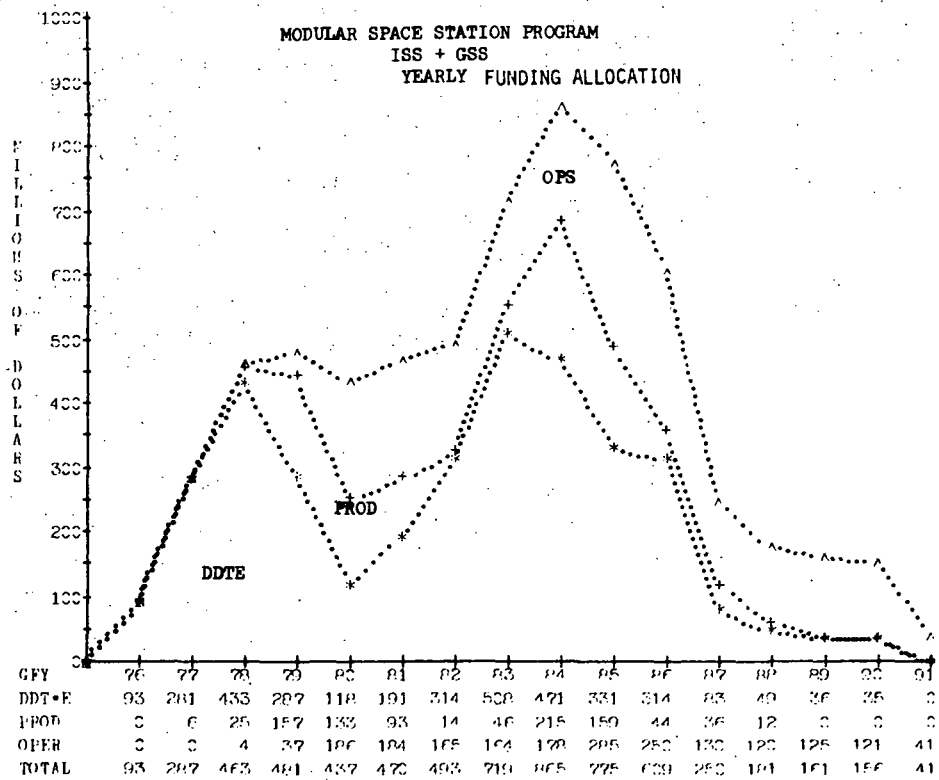


GFY	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91
DDT+E	93	281	433	287	118	191	314	500	471	331	314	63	49	36	25	0
PROD	0	6	25	157	133	93	14	46	215	159	44	36	12	0	0	0
OPER	0	0	4	37	186	184	165	154	179	295	252	130	125	125	121	41
TOTAL	93	287	463	481	437	470	493	719	865	785	609	259	191	161	146	41

Figure 2-1. Total Modular Space Station Program Funding

Details of the project level, system level, and subsystem level costs are presented in subsequent sections of these volumes. The detail estimates have been developed at one or more levels below those being reported, and have been generated using the MDAC previously developed LEADER I computerized cost model, which has contributed to the credibility, consistency, and traceability of the cost estimates.

2.1.2 Cost Assumptions, Ground Rules and Rationale

Cost estimates have been developed in consonance with the Work Breakdown Structure (WBS) as presented in the Space Station Phase B Extension Study Plan, (MDC-G2127, March 1971), and as defined in Appendix A.

Cost estimates are commensurate with the program definitions available at this time, the relative level of study effort, and with the understanding that the estimates are only for preliminary planning and tradeoff study purposes.

Costs are stated in Government Fiscal Year 1972 dollars.

Costs are reported by Government Fiscal Year: 1 July through 30 June.

Cost estimates reflect the baseline definition and mission profile as published in the Baseline Program and System Definition Document (Change G), 6 August 1971, with the following comments.

The cost estimates encompass both ISS and GSS capabilities. The ISS capability includes a Power/Subsystems Module, a (6-man) Crew/Operations Module, a General Purpose Laboratory Module, and four Logistics Modules. The GSS consists of one additional Power/Subsystems Module, one additional (6-man) Crew/Operations Module, and four Crew Cargo Modules, two of which are modified from existing Logistics Modules.

Costs of the Space Station Modules assume optimum commonality as a prime consideration; that a single prime contractor will have responsibility for designing and producing all of the modules; that the same designs for one module will be employed to an optimum extent for succeeding modules; and that there will be no technology increase during the program.

The Space Station Project cost estimates reflect the reduced testing program concept made possible by the concept of commonality. Cost of the Test Articles "N" for the Space Station Modules and for the Logistics Modules include restoration and assembly of existing subsystems development test hardware for incorporation into the Functional Model (FM), and existing qualification test hardware for incorporation into the Flight Integration Tool (FIT).

Prime Contractor costs for installation and integration of the subsystems into the Space Station Modules have been included in the Installation and Integration subsystem costs. Prime Contractor costs for integrating the Space Station Modules have been included in the System Level WBS Box titled System Integration. The system Level WBS item titled System Support includes costs for integration of Space Station Modules and other modules, such as Logistics Modules and RAM's.

The Space Station Project costs do not provide for an artificial-g experiment.

The cost estimates reflect current employment levels (calendar 1968 to 1971) and a 6-percent (compounded annually) inflation factor to derive values in terms of GFY 1972 dollars. Thus, the estimates assume that award of this project would return prime contractor and subcontractor employment to the 1968 to 1971 levels.

The cost estimates assume all applicable Supporting Research and Technology (SRT) will be available when needed.

Production (recurring) costs include the cost of flight articles, with no provision for any backup.

The Space Shuttle Operations costs are based on a requirement for 114 Shuttle launches. Shuttle Project costs reflect only operations (recurring) costs at $4.5 million per launch, per NASA direction.

NASA effort for Program Management and System Support has been excluded by NASA direction. Project Level costs include Project Management and Systems Support for the Space Station Project and the RAM Project, but not the Shuttle Project. Thus, the NASA institutional base has been excluded.

Nonflight hardware used as ground test articles for crew training, simulation, or problem evaluation are assumed to be developed, operated, and maintained by the NASA.

Recurring (operations) costs do not include the cost of any modifications to the MSFN, since no modifications have been identified as being required. The costs assume that the Ground Network and Synchronous Satellite System is provided at no cost to the Modular Space Station Program.

Estimated costs for the RAM Project and for the Integral Experiment "N's" in the Space Station Project have been developed in association with Martin-Marietta Corporation based on the NASA Experiments Blue Book, 1 April 1971, and the Case No. 534G definition.

Cost estimates for the Space Station Project have been based upon costs derived from cost history on the Skylab, Gemini, S-IVB Stage, MOL, and other NASA-funded studies, from direct quotations, and from the establishment of cost relationships reflecting Modular Space Station Program requirements.

Production (recurring) cost estimates have been derived using cost estimating relationships (CER's) developed from data on subsystems most similar to the Modular Space Station subsystems by classification as to type, function, class, operating mode, technology, and design life.

DDT&E (nonrecurring) costs have been estimated from ratios developed from studies of recurring-to-nonrecurring cost relationships, adjusted to Modular Space Station definitions, requirements and programmatic concepts. The ratios include development and qualification test hardware at the Subsystem Level.

Operations (recurring) costs have been derived from consideration of the innovative concepts responsive to Modular Space Station requirements, including program schedule and mission profile. Launch operations costs include launch site operations, using a Task Force concept, with the majority of the launch crew composed of personnel who assembled and checked out the Space Station prior to delivery to the launch site. Launch operations also includes inplant support. Flight operations costs include Prime Contractor costs for Mission Analysis and Planning, Flight Operations Support, Experiment Support Operations, and Logistics Operations Support. NASA and support agency tasks have been excluded by NASA direction. Costs for 10 years of spares have been included under Operations (Recurring) for the subsystems of the Space Station Modules and for the Flight Integration Tool.

2.1.3 Modular Space Station Program Schedule

The Modular Space Station Program baseline schedule (see Figure 2-2) provides a 6-man Space Station crew capability with a Growth Space Station (GSS) subsequently planned for 12 men. Three major activities are required to achieve the schedule: (1) a supporting research and technology (SRT) program in direct support of the Modular Space Station concept,

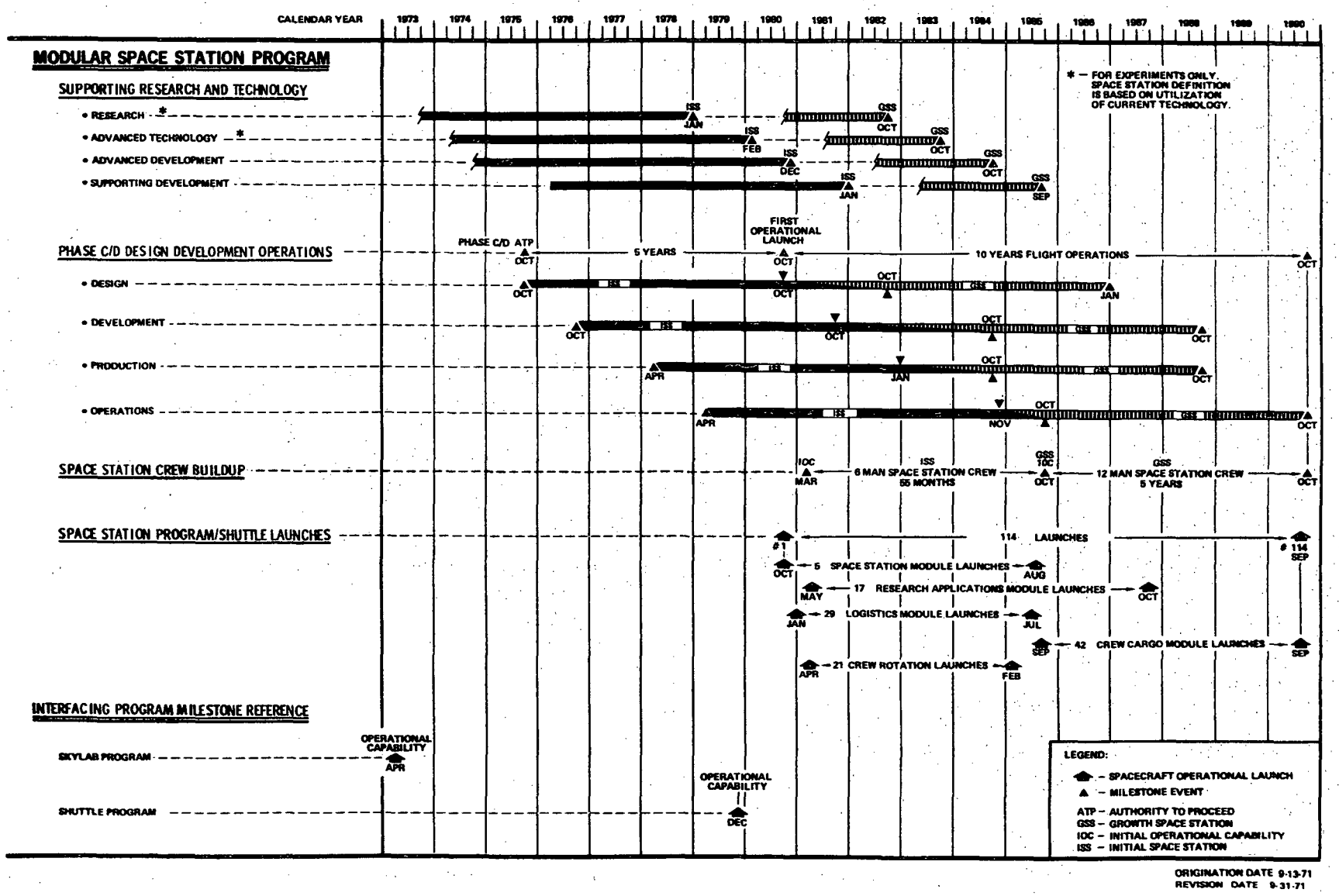


Figure 2-2. Modular Space Station Program Schedule

(2) a combined design, development and operations (Phase C/D), and (3) the development of the Shuttle Program in essentially the same development period and in parallel with the Modular Space Station Program.

Time phasing within the SRT program was established coincident with requirements for definition, design, and development of the program systems. For example, substantial results from research and advanced technology efforts are needed prior to Phase C/D authority to proceed (ATP). Advanced development will contribute to the early Phase C/D and will not be applicable if received too late in Phase D. Supporting development activity decision action will occur several months before final engineering design is complete.

The schedule is based on a Phase C/D design, development, and operations authority to proceed (ATP) in October 1975. Design, development, test and evaluation (DDT&E) of the Space Station Modules for the initial 6-man crew capability requires 5 years and is complete at the first Space Station Module operational launch in October 1980. Test article development continues to October 1984 to support Integral Experiment integration. Ten years of flight operations are assumed beginning with the first operational launch and are complete in October 1990. Production (recurring) begins with the manufacturing detail fabrication start of the first projected operational vehicle which overlaps DDT&E by 30 months. Operations begin with Site Activation, April 1979, 13 months before initial delivery of the first Logistics Module to KSC.

The engineering design and development will begin at Phase C/D ATP in October 1975. The initial 100-percent drawing release complete occurs April 1978, 30 months after ATP. Completion of the Space Station Modules (SSM) preliminary design review (PDR) is scheduled for October 1976, 12 months after ATP, to establish the firm vehicle configuration and provide an understanding of all the parameters required to meet the program objectives. A SSM critical design review (CDR) evaluation will be completed in October 1977, 24 months after ATP, to assure that specified design requirements have been met.

The ground test program will require test articles which will be used primarily to satisfy various development integration, and multiple testing objectives. Test models at the subsystem level and below will be required of breadboard, prototype, and flight types. These subsystem models will be used for concept and design development and design qualification. Qualification of subsystems will be complete in October 1979, 4 years after ATP.

At the system level, two test articles are required for the development phase. The system level test articles will be used in the ground test program for subsystem integration and interface verification activities. The test articles are the Functional Model and the Flight Integration Tool. The planning has been organized to limit the test articles to a minimum number that satisfy the system level development and operational requirements including integration of experiments and Ground Support Equipment. An example of this is the use of the Flight Integration Tool for (1) manufacturing development and tool fabrication; (2) factory system integration and interface verification testing, software development, and operating procedure development; and (3) factory integration and checkout of new or modified subsystem equipment required during the flight operations phase.

The Functional Model (FM) is a development tool that will functionally represent an operational vehicle, but in a rack and panel type assembly. The FM will consist of qualifiable-type, prototype, flight-equivalent, and simulated aerospace vehicle equipment (AVE). The major objective of the FM is to perform interface development testing among AVE subsystems and between AVE subsystems and ground support equipment in preparation for support of the system-level development testing. The requirements are to establish the integration of subsystems, development of software, and development of procedures. The FM will be in continuous use throughout the subsystem and system development.

The Flight Integration Tool initially will be used for manufacturing development and tool fabrication and will provide a check of the physical compatability of subsystem design configurations early in their development. The primary test objectives are as follows.

A. To verify manufacturing methods
B. To check assembly procedures
C. To assist in determining tooling requirements
D. To establish control line and cable routing
E. To establish electrical wire harness routing
F. To verify component accessibility
G. To develop and verify maintenance procedures
H. To facilitate design change feedback
I. To serve as an additional man-system procedure definition tool
J. To verify mechanical clearances

The Flight Integration Tool will subsequently be used to verify complete development at the factory and will include people, procedures, facilities and production equipment. This FIT will be produced in the same factory manufacturing and testing facilities where the operational vehicle will be produced. It will be developed in a production-like manner and acceptance tested. The Flight Integration Tool will be used to perform system integration and interface verification testing, software verification, and operating procedure verification. Upon completion of these tests, the Flight Integration Tool will be maintained as a development tool for integration and interface verification of new or modified experiments and subsystem equipment for on-orbit installation during the flight operations phase.

The flight operations begin with three Space Station Shuttle launches which deliver to the planned orbit a Power/Subsystem Module, a Crew/Operation Module, and a General Purpose Laboratory Module. The Space Station modules are launched at 30-day intervals beginning with the first launch in October 1980. All modules can be docked in sequence with a single docking operation. Early Space Station buildup orbit activities of the unmanned vehicle consists of solar array deployment, including vehicle orientation and alignment, power system activation, antenna deployment, and preliminary subsystem checks. The orbit emphemeris data and station habitability verification are the remaining key events of early orbit. Mission control center evaluates the data and signals the "go" for manning.

Four Logistics Modules (LOG M) are required to support the initial 6-man Space Station crew capability flight operations. Ninety days after the first Space Station module launch, the first Shuttle (LOG M) is launched and delivers a 2-man crew for initial Space Station activation and experiment operations. The third Shuttle LOG M launch in March 1981 establishes the 6-man Space Station operational capability 5 months after first Space Station launch. A total of 29 Shuttle LOG M launches are required over a period of 55 months to support the 6-man crew capability flight operations phase.

Five Space Station attached Research Application Modules (RAM) are required for the Initial Space Station experiment program. The first Shuttle RAM launch occurs in May 1981, 7 months after the first Space Station operational launch. Four more attached RAM's are launched over the next 33 months. The last Shuttle RAM launch of the ISS phase is February 1984, 20 months before the completion of ISS operations.

DDT&E for the GSS 12-man capability begins with the start of design for the Integral Experiments and Experiment "N" in October 1980. DDT&E for the Space Station Modules requires 42 months and is complete at the first GSS Space Station module operational launch in May 1985. Test article development continues to October 1988 to support free-flying module experiment integration. GSS production begins with the manufacturing detail fabrication start of the first GSS Attached RAM Module and Experiment "N" in April 1983. Operations begin with reactivation of Launch Operations GSE in November 1984, 4 months before the GSS Crew Operations module is delivered to KSC.

The technology of initial capability modules will be maintained for the GSS including common structural, thermal, and docking design for all modules. The engineering drawing release for GSS Space Station Modules will occur in January 1982, 27 months after DDT&E go-ahead. Final engineering drawing release for Experiment Ground Support equipment is in March 1985, 53 months after DDT&E go-ahead. The GSS Space Station Modules PDR and CDR are scheduled for March 1982 and September 1982, 17 months and 23 months, respectively, after DDT&E go-ahead.

The GSS requires two additional Space Station modules to achieve the 12-man operational flight program. Two 6-man Crew Cargo Modules (CCM) are required in addition to two LOG M's reconfigured to CCM's from the Initial Space Station operational program for a total of four CCM's to support the GSS crew rotation and cargo supply requirements.

A 12-man GSS orbit configuration is achieved in October 1985 with four Shuttle launches which include a second Crew/Operations Module, a second Power/Subsystem Module and two CCM's. The 12-man orbit configuration is maintained for a period of five years. A total of two Space Station modules, 42 CCM, and 12 RAM Shuttle launches are required to support the GSS flight operations phase.

The Modular Space Station Program requires five Space Station modules, 42 CCM, 29 LOG M, 17 RAM and 21 Shuttle-only launches. The initial Space Station Shuttle launches occur at a maximum launch-rate interval of 30-days. The Growth Space Station Shuttle launches occur at a maximum launch-rate interval of 30 days, with seven exceptions which occur at 60-day intervals. A total of 114 Shuttle launches occur over a period of 10 years.

2.1.4 Funding Distribution (ISS + GSS)

Figure 2-3 is a summary chart which highlights the relationships of the cost estimates to technical characteristics and schedules. It also presents an overview of the funding allocations, both yearly and cumulatively by Government Fiscal Year (Mid-Year Plot). Funding has been spread using summations of subordinate level fundings.

MODULAR SPACE STATION PROGRAM

ISS + GSS

TECHNICAL DESCRIPTION

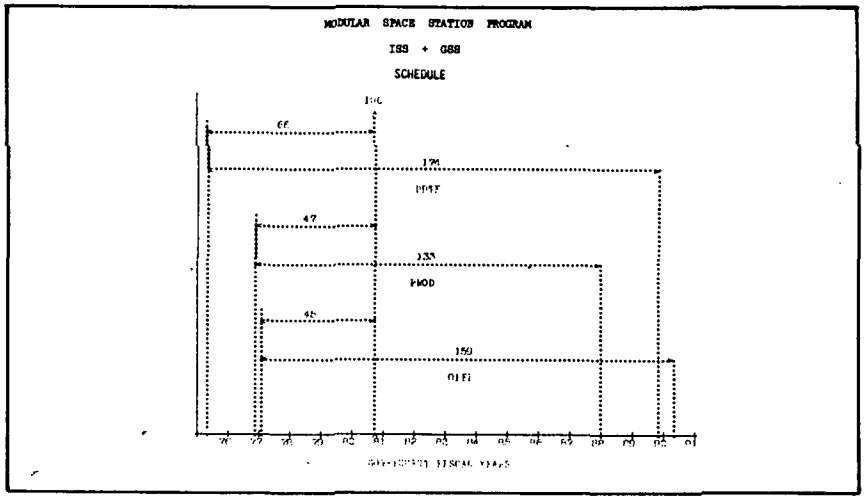
MODULAR SPACE STATION PROJECT

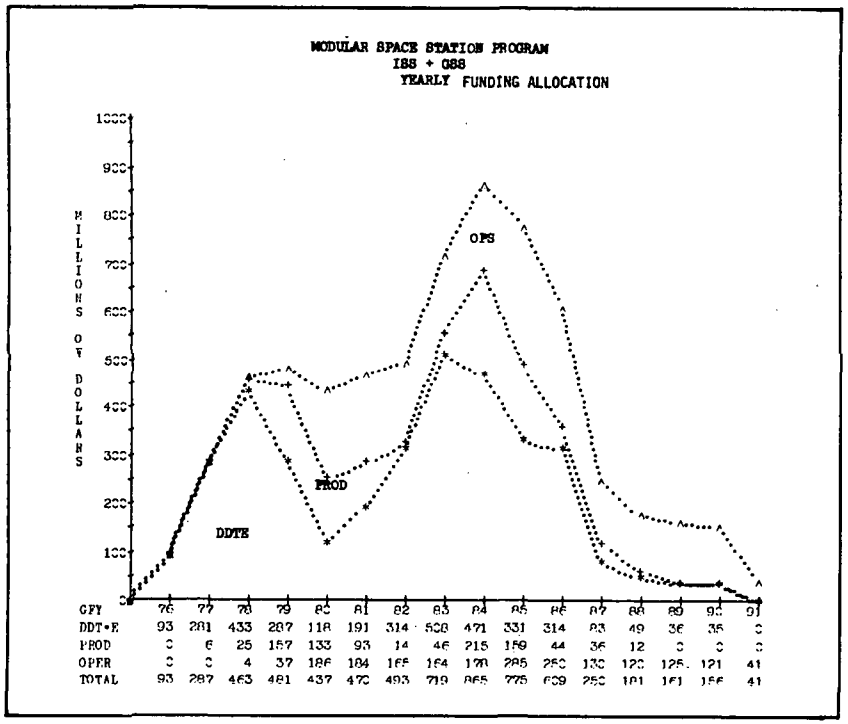
MAJOR HARDWARE:	(2)	POWER/SUBSYSTEMS MODULES
	(2)	CREW(6)/OPERATIONS MODULES
	(1)	GFL MODULE (INCLUDING INTEGRAL EXPERIMENTS)
	(4)	LOGISTICS MODULES
	(4)	CREW/CARGO MODULES (INCL. MOD. 2-LOGISTICS MODULES)

RAM PROJECT

MAJOR HARDWARE:	(3)	FREE-FLYING MODULES
	(14)	ATTACHED MODULES (INCL. RE-WORK OF 3)
	(17)	FFE'S - NASA BLUE BOOK (APRIL 1971) (CASE 534G)

SPACE SHUTTLE OPERATIONS 114 FLIGHTS





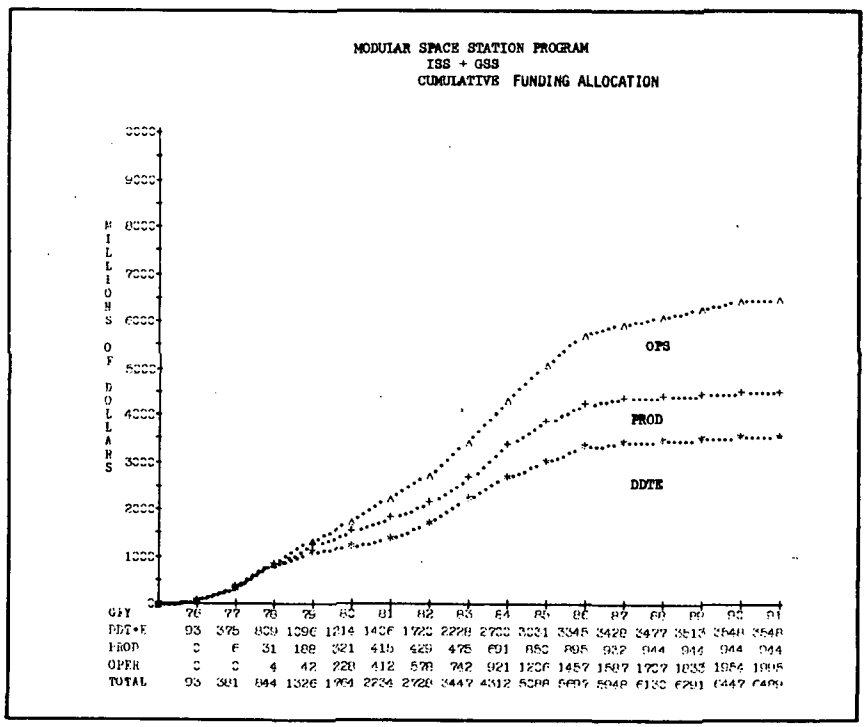


Figure 2-3. Modular Space Station Program Summary Chart

Section 3

PROJECT - LEVEL 3

This section presents the summary costs and schedules for the three projects which make up the Space Station Program.

A. Shuttle Operations
B. Modular Space Station Project
C. RAM Project

3.1 SHUTTLE OPERATIONS (ISS + GSS) (WBS 1X800)

3.1.1 Summary

The Space Station Modules, Logistics Modules, Research Applications Modules, and Space Station crewmen are transported into orbit onboard the orbiting vehicle of the Space Shuttle Program. During the ISS phase of the Space Station Program, the SSM's, RAM's, and LOG M's are transported in the cargo bay of the Orbiter. The Space Station crewmen are transported as passengers in the cabin of the Orbiter (two SSM crewmen on each flight). During the GSS phase, both the crew and cargo are transported in a Crew Cargo Module. The Space Shuttle operations include the launch and flight operations cost for all flights in support of the Space Station and RAM Projects. These costs were supplied by NASA and are currently identified as $\$4.5 \times 10^6$/flight. This is based on a fully reusable shuttle.

Definition

The task definition of this WBS Box is contained in Appendix A.

Cost Assumption, Ground Rules and Rationale

None in addition to those in Section 2.1.2.

3.1.2 Schedule

Shuttle launch operations (see Figure 3-1 Shuttle Operations Schedule) are initiated in October 1980, with the first operational launch of the Space

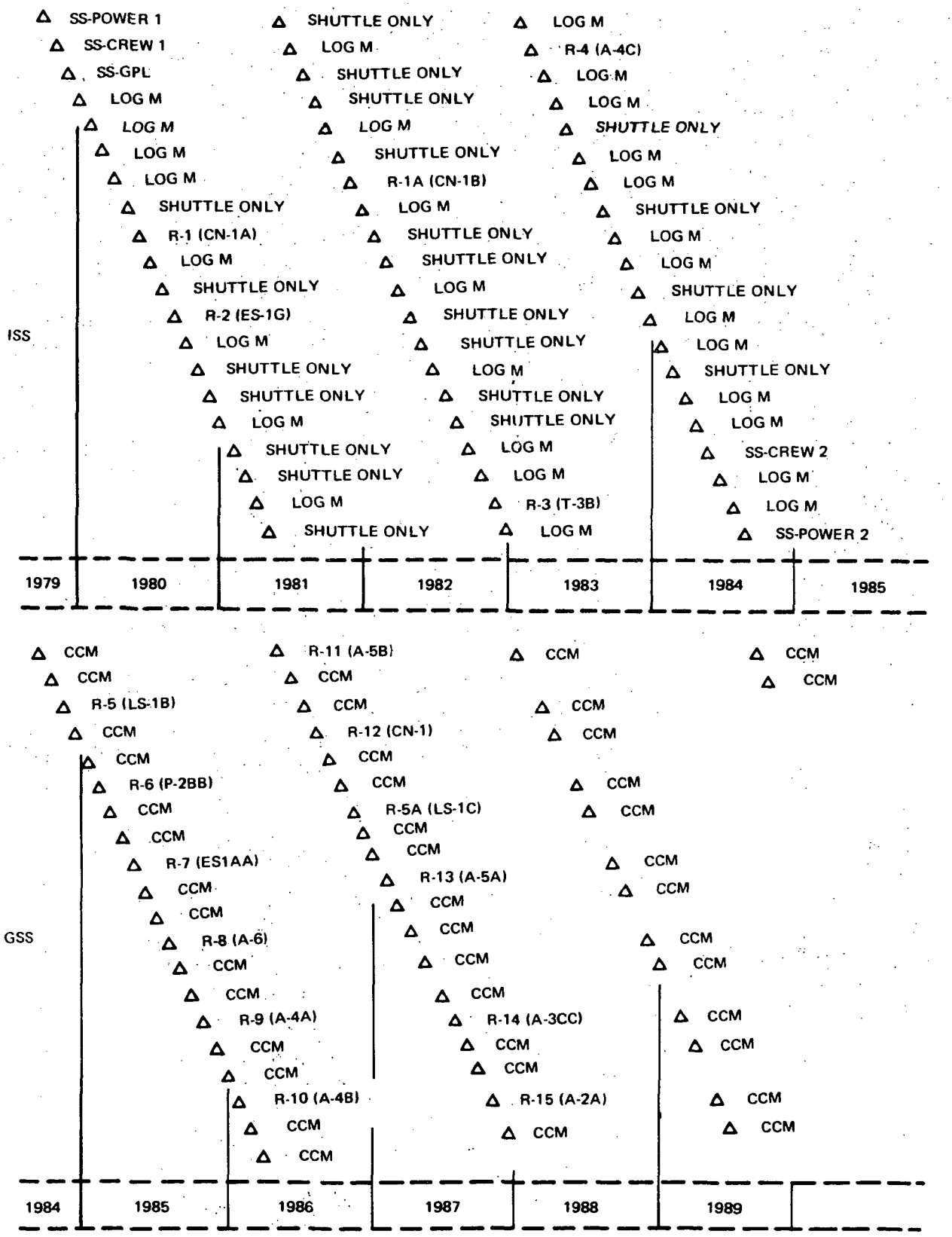


Figure 3-1. Shuttle Operations Schedule

Station Power/Subsystem Module. The SSM Crew/Operations Module and General Purpose Laboratory Modules follow in successive Shuttle launches 30 days apart. The fourth Shuttle launch carries a Logistics Module and the 2-man SSM activation crew to the Space Station in January 1981. Two additional LOG M 2-man SSM crew launches achieve the 6-man in-orbit Initial Operational Capability (IOC) of the Space Station Program in March 1981. Each man of the 6-man crew is on orbit 90 days. Two-man crew rotation takes place every 30 days. The Shuttle 30-day launch cycle satisfies this requirement as well as transporting RAM's and LOG M's to the Space Station at designated intervals.

Three Space Station/Shuttle launches, 29 LOG M/Shuttle launches and 21 crew rotation/Shuttle launches are required to complete the ISS phase of the Space Station Program in October 1985.

3.1.3 Costs

3.1.3.1 Cost Methodology

Operations costs have been calculated based on 114 flight at $4.5 million per flight.

3.1.3.2 Cost Estimate

The total cost is estimated to be $513 million, all of which is operations cost. It is estimated that the operations effort will begin 6 months prior to the milestone launch date of October 1980, and will continue for 120 months.

3.2 MODULAR SPACE STATION PROJECT–PROJECT TOTAL (WBS 1X200) (ISS + GSS) (ISS ONLY) (GSS ONLY)

3.2.1 Summary

The Modular Space Station Project includes the Space Station Modules, Logistics Module, Crew Cargo Module, and Integral Experiment Flight Equipment. In addition to the flight hardware systems, there is the Experiment Integration, Test Articles, Ground Support Equipment, Facilities, System Support, Project Management, Launch Operations and Flight Operations required to support the design, development, launch and mission

operations. The total cost of the Space Station Project (ISS + GSS) has been estimated to be $3, 592 million. As shown in Table 3-1 this total cost includes $1693 million for DDTE, $692 million for production, and $1207 million for operations.

ISS flight operations begin with three Space Station Shuttle launches which deliver to the planned orbit a Power/Subsystem Module, a Crew/Operations Module, and a General Purpose Laboratory Module.

The ISS cost of the Space Station Project has been estimated to be $2245 million. As shown in Table 3-2, this total cost includes $1246 million for DDTE, $380 million for production, and $620 million for operations.

The GSS requires two additional Space Station modules to achieve the 12-man crew operational flight program. Four 6-man Crew Cargo Modules (CCM) are required to support the GSS crew rotation and cargo supply operational flight requirements. Two CCM's are manufactured and two LOG M's from the ISS are reconfigured to CCM's. The GSS cost of the Space Station Project has been estimated to be $1347 million. As shown in Table 3-3, this total cost includes $447 million for DDT&E, $313 million for production, and $587 million for operations.

Definition

The task definition of this WBS Box is contained in Appendix A.

Cost Assumptions, Ground Rules and Rationale

None in addition to those in Section 2.1.2.

3.2.2 Modular Space Station Project Schedule

The schedule (Figure 3-2) covers design, development, and operations activities required to design, test, produce, and operate the Modular Space Station Project systems. It provides major milestones, key events, and critical actions pertaining to the project and its systems that are vital to the timely execution of the program. Interrelated activities are presented with

Table 3-1

MODULAR SPACE STATION PROJECT-
PROJECT TOTAL ESTIMATED COST

(ISS + GSS)

1972 Dollars in Millions

WBS	Title	C	DDT&E	Production	Operations	Total
2X034	Project Management	3	78	32	58	167
2X052	Experiment Integration	2	124	0	0	124
2X064	System Support	3	67	55	184	306
2X081	FIT Article	3	199	0	86	285
2X082	FM Article	3	69	0	0	69
2X124	Facilities	2	28	0	0	28
2X261	LOG M GSE	2	14	0	0	14
2X269	SSM GSE	2	27	0	0	27
2X279	Launch GSE	2	1	0	0	1
2X289	Flight GSE	2	14	0	0	14
2X299	Test Article	2	0	0	0	0
2X309	Experiment GSE	2	45	0	0	45
2X491	Launch Operations	3	0	0	109	109
2X591	Flight Operations	3	0	0	416	416
2X751	Power Module	3	212	77	85	374
2X752	Crew Module	3	132	73	84	289
2X753	GPL Module	3	109	50	51	211
2X754	Power Module	3	63	85	37	185
2X755	Crew Module	3	48	80	37	165
2X759	SS Integration	3	152	176	41	370
2X761	Logistics Modules	3	62	46	11	118
2X762	Crew Cargo Modules	2	40	18	8	66
2X999	Experiment N	2	209	0	0	209
(3)	Project Total		1,693	692	1,207	3,592

Table 3-2.

MODULAR SPACE STATION PROJECT-
PROJECT COST ESTIMATE

(ISS ONLY)

1972 Dollars in Millions

WBS	Title	C	DDT&E	Production	Operation	Title
2X034	Project Management	3	57	18	29	103
2X052	Experiment Integration	2	96	0	0	96
2X064	System Support	3	50	30	88	168
2X081	FIT Article	3	118	0	55	173
2X082	FM Article	3	43	0	0	43
2X124	(5) Facilities	2	28	0	0	28
2X261	LOG M GSE	2	14	0	0	14
2X269	(5) SS GSE	2	27	0	0	27
2X279	Launch GSE	2	1	0	0	1
2X289	Flight GSE	2	14	0	0	14
2X299	Test Article GSE	2	0	0	0	0
2X309	Experiment GSE	2	37	0	0	37
2X491	Launch Operations	3	0	0	54	54
2X591	Flight Operations	3	0	0	230	230
2X751	Power Module	3	212	77	53	342
2X752	Crew Module	3	132	73	53	258
2X753	GPL Module	3	109	50	30	190
2X759	SS Integration	3	111	94	20	226
2X761	Logistics Modules	3	42	37	8	86
2X999	Experiment N	2	156	0	0	156
	Project Total		1246	380	620	2245
	Percent		55	17	28	100

Table 3-3

MODULAR SPACE STATION PROJECT–
PROJECT COST ESTIMATE

(GSS ONLY)

1972 Dollars in Millions

WBS	Title	C	DDT&E	Production	Operations	Total
2X034	Project Management	3	21	14	29	64
2X052	Experiment Integration	2	29	0	0	29
2X064	System Support	3	17	25	97	139
2X081	FIT Article	3	81	0	31	112
2X082	FM Article	3	26	0	0	26
2X309	Experiment GSE	2	7	0	0	7
2X491	Launch Operations	3	0	0	55	55
2X591	Flight Operations	3	0	0	185	185
2X751	Power Module	3	0	0	32	32
2X752	Crew Module	3	0	0	31	31
2X753	GPL Module	3	0	0	21	21
2X754	Power Module	3	63	85	37	185
2X755	Crew Module	3	48	80	37	165
2X759	SS Integration	3	41	82	21	144
2X761	Logistics Modules	3	20	9	3	33
2X762	Crew Cargo Modules	2	40	18	8	66
2X999	Experiment N	2	53	0	0	53
	Project Total		447	313	587	1347
	Percent		33	23	44	100

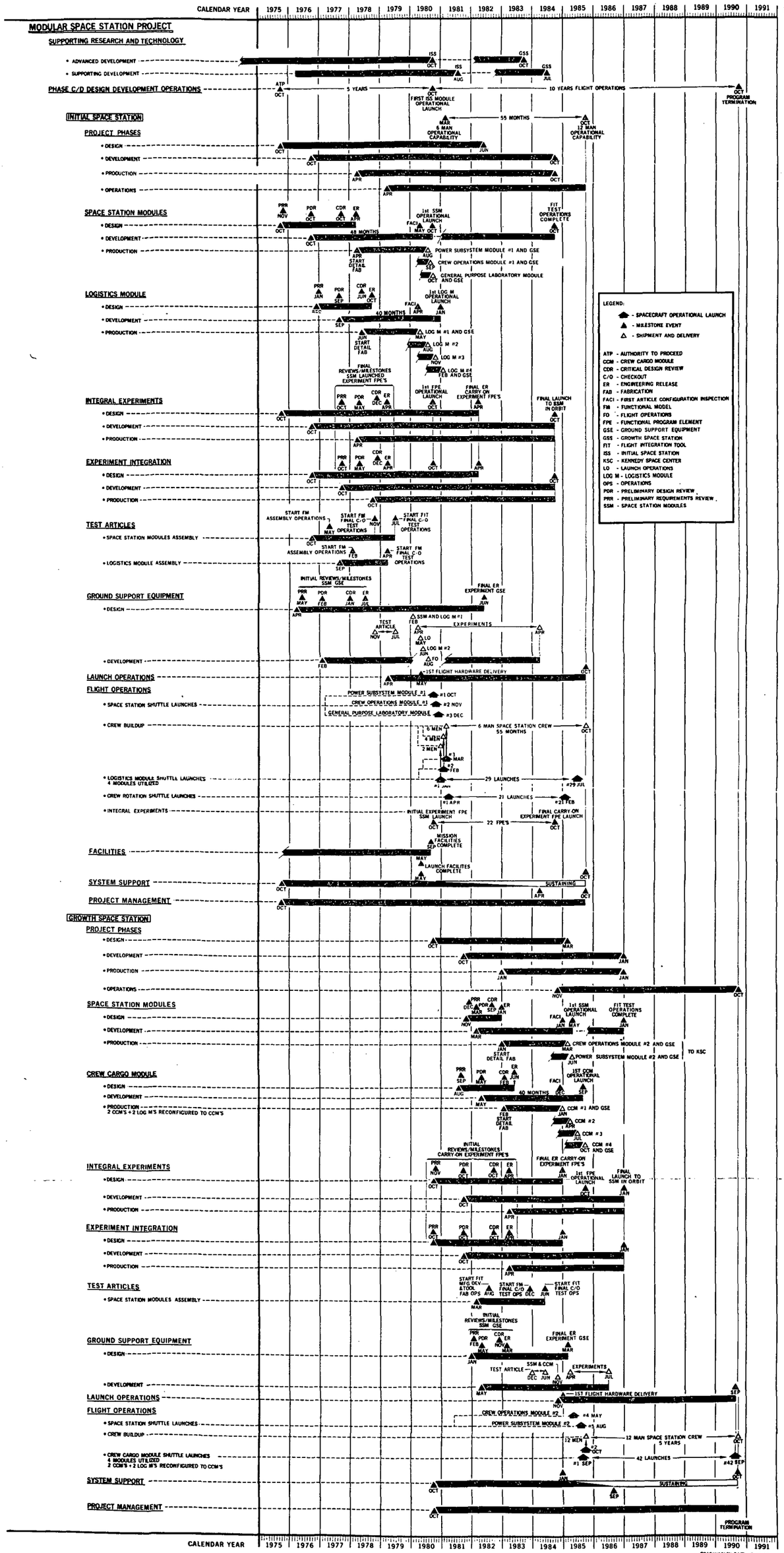


Figure 3-2. Space Station Project Schedule

logic, feasibility, and maximum application of existing technology and capability.

The schedule provides an Initial Space Station (ISS) 6-man crew capability with a subsequent Growth Space Station (GSS) planned for 12 men. Three major activities are required to achieve the schedule: (1) a supporting research and technology (SRT) program in direct support of the Modular Space Station concept, (2) a combined design, development and operations (Phase C/D), and (3) the development of the Shuttle Program.

Time phasing within the SRT program was established coincident with requirements for definition, design, and development of the project systems. For example, substantial results from research and advanced technology efforts are needed prior to Phase C/D authority to proceed (ATP). Advanced development will contribute to the early Phase C/D and will not be applicable if received too late in Phase D. Supporting development activity decision action will occur several months before final engineering design is complete.

The schedule is based on a Phase C/D design, development and operations ATP in October, 1975. The first operational launch occurs 5 years after ATP, October 1980. Ten years of flight operations are assumed beginning with the first operational launch and are complete in October 1990.

The ISS Space Station Project design phase begins at Phase C/D ATP October 1975 with design start of the Space Station Module (SSM) and Integral Experiment systems. Design is complete at final engineering release (ER) of the experiment Ground Support Equipment system in June 1982. The development phase is initiated October 1976, 1 year after design start and is complete at the conclusion of Flight Integration Tool test operations in October 1984. The operations phase begins with Site Activation in April 1979, 1 year after the start of production and 13 months before delivery of the first Logistics Module. The operations phase is complete at the start of GSS 12-man crew flight operations October 1985.

The ISS Space Station Modules are launched at 30-day intervals beginning with the first launch October 1980. All modules can be docked in sequence with a single docking operation. Early Space Station buildup orbit activities of the unmanned vehicle consists of solar array deployment, including vehicle orientation and alignment, power system activation, antenna deployment, and preliminary subsystem checks. The orbit ephemeris data and station habitability verification are the remaining key events of early orbit. Mission control center evaluates the data and signals the "go" for manning.

Four Logistics Modules (LOG M) are required to support ISS flight operations. Ninety days after the first Space Station Module launch, the first Shuttle Log M is launched and delivers a 2-man crew for Space Station activation operations. Space Station activation is complete and the 6-man ISS crew is established at the third Shuttle Log M Launch in March 1981. The first crew rotation Shuttle-only launch occurs in April 1981. A total of 29 Shuttle Log M launches and 21 crew rotation Shuttle-only launches are required over a period of 55 months to support the 6-man crew ISS flight operations phase.

Design, development, test, and evaluation (DDT&E) for the GSS 12-man capability coincides with ISS first operational launch, October 1980. The first GSS operational launch occurs 55 months after DDT&E start in May 1985. The technology of ISS modules will be maintained for the GSS including common structural, thermal, and docking design for all modules.

The GSS Space Station Project design phase begins October 1980 with design start of the Integral Experiment system. Design is complete at final ER of the experiment Ground Support Equipment system March 1985. The development phase is initiated in October 1981, 1 year after design start and is complete at the conclusion of Flight Integration Tool test operations in January 1987. The production phase begins with the manufacturing detail fabrication start of the first SSM operational vehicle in January 1983 and

occurs 28 months before the first operational launch in May 1985. The production phase is complete 20 months after the first operational launch. The operations phase begins with the reactivation of launch operations GSE at the launch site in November 1985 and is complete at the termination of the program in October 1990.

A 12-man GSS orbit configuration is achieved in October 1985 with four Shuttle launches which include a second Crew/Operations Module, a second Power/Subsystem Module, and two CCM's. The 12-man orbit configuration is maintained for a period of 5 years. A total of two Space Station modules and 42 CCM Shuttle launches are required to support the GSS flight operations phase.

3.2.3 Funding Distribution

Cost Methodology

The estimated costs have been developed from summations of cost estimates at subordinate levels. The subordinate cost estimates were developed at one or more levels below those being reported. The costs reported at this level include the cost of integrating the elements at the subordinate levels.

Funding Distribution (ISS + GSS)

Figure 3-3 is a Summary Chart which highlights the relationships of the cost estimates to technical characteristics and schedules. It also presents an overview of the funding allocations, both yearly and cumulatively by Government Fiscal Year (Mid-Year Plot). Funding has been spread as the summation of subordinate level funding.

Funding Distribution (ISS Only)

Figure 3-4 is a Summary Chart which highlights the relationships of the cost estimates to technical characteristics and schedules. It also presents an overview of the funding allocations, both yearly and cumulatively by Government Fiscal Year (Mid-Year Plot). Funding has been spread as the summation of subordinate level funding.

MODULAR SPACE STATION PROJECT TECHNICAL DESCRIPTION WBS 200

ISS + GSS

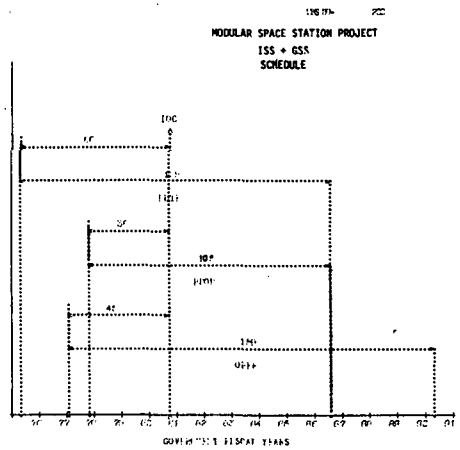
MAJOR HARDWARE

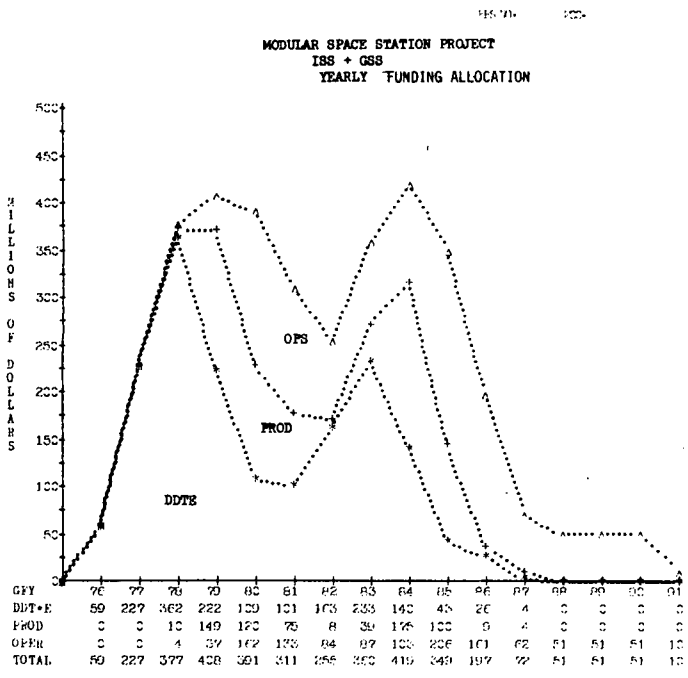
	ISS	GSS	TOTAL
POWER/SUBSYSTEMS MODULES (14 FT. DIA. X 58 FT. LONG)	1	1	2
CREW (6)/SUBSYSTEMS MODULES (14 FT. DIA. X 45 FT. LONG)	1	1	2
GPL MODULE CONTAINING INTEGRAL EXPERIMENTS (14 FT. DIA. X 45 FT. LONG)	1	-	4
LOGISTICS MODULES (14 FT. DIA. X 28 FT. LONG)	4	-	4
CREW/CARGO MODULES (14 FT. DIA. X 28 FT. LONG)	-	4*	4

* INCLUDING 2 MODIFIED LOGISTICS MODULES

RELATED HARDWARE AND SUPPORT

TEST ARTICLES	- SUPPORT DEVELOPMENT AND OPERATIONS OF SPACE STATION MODULES, LOGISTICS MODULES, CCM'S
GSE	- SPACE STATION MODULES, LOGISTICS MODULES, CCM'S, EXPERIMENTS, TEST ARTICLES, LAUNCH OPERATIONS, FLIGHT OPERATIONS
FACILITIES	- MODIFICATIONS FOR DEVELOPMENT, PRODUCTION, OPERATIONS
OPERATIONS	- CONTRACTOR LAUNCH AND FLIGHT OPERATIONS SUPPORT
INTEGRATION	- EXPERIMENTS INTO GPL; SPACE STATION MODULES SYSTEM





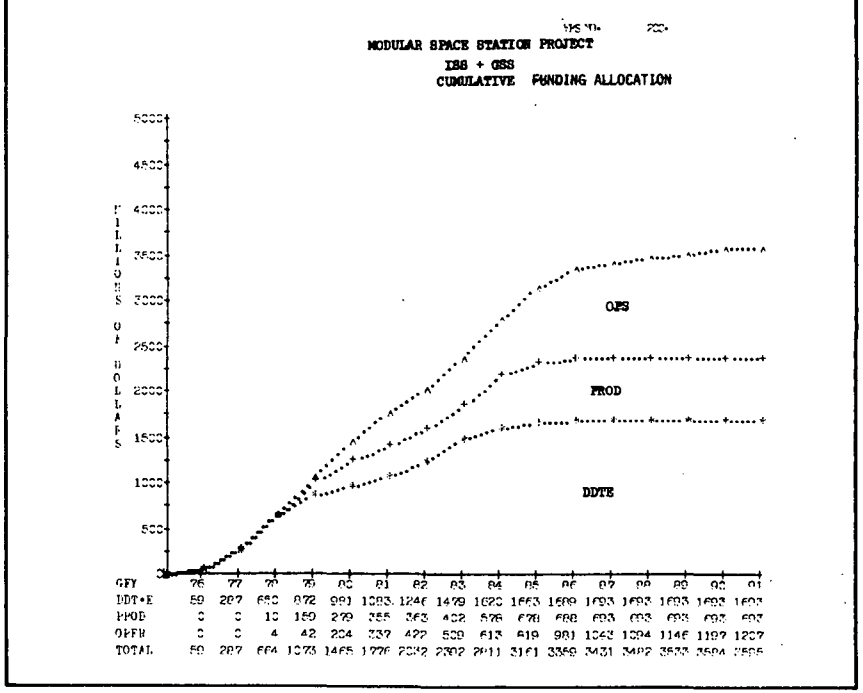


Figure 3-3. Modular Space Station Project Summary Chart

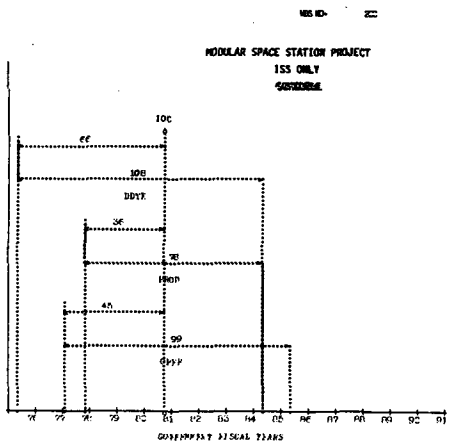
MODULAR SPACE STATION PROJECT TECHNICAL DESCRIPTION WBS 200
ISS ONLY

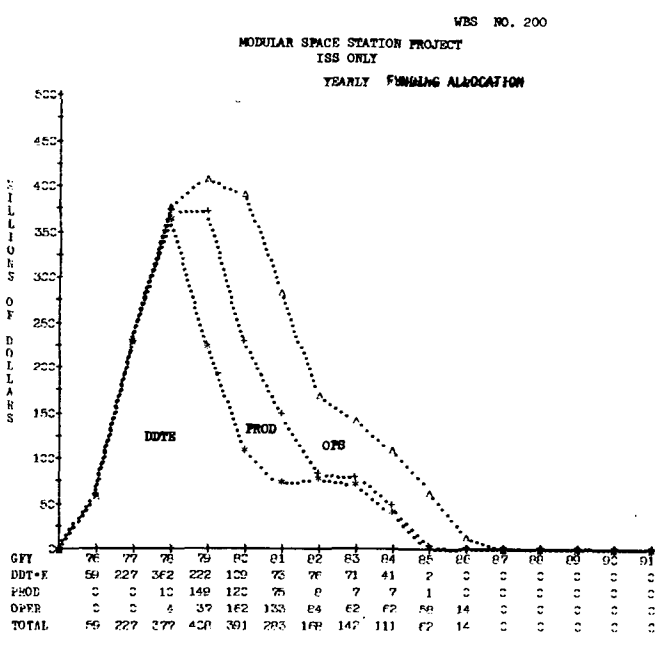
MAJOR HARDWARE

(1) POWER/SUBSYSTEMS MODULE (14 FT. DIA. X 58 FT. LONG)
(1) CREW (6)/OPERATIONS MODULE (14FT. DIA. X 45 FT. LONG)
(1) GFL MODULE CONTAINING INTEGRAL EXPERIMENTS (14 FT. DIA. X 45 FT.LONG)
(4) LOGISTICS MODULES (14 FT. DIA. X 28 FT. LONG)

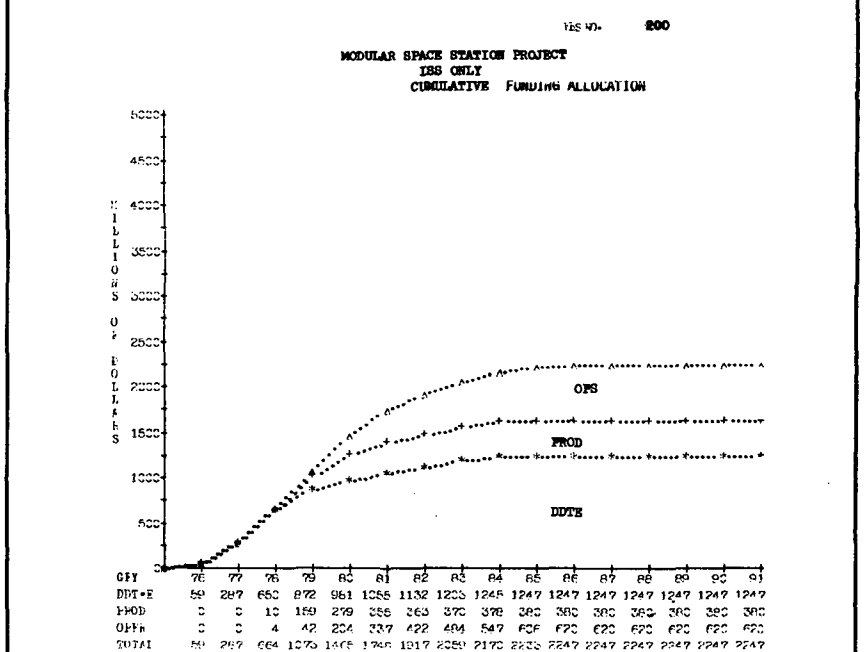
RELATED HARDWARE AND SUPPORT

TEST ARTICLES	-	SUPPORT DEVELOPMENT AND OPERATIONS OF SPACE STATION MODULES, LOGISTICS MODULES
GSE	-	SPACE STATION MODULES, LOGISTICS MODULES, EXPERIMENTS, TEST ARTICLES, LAUNCH OPERATIONS, FLIGHT OPERATIONS
FACILITIES	-	MODIFICATIONS FOR DEVELOPMENT, PRODUCTION, OPERATIONS
OPERATIONS	-	CONTRACTOR LAUNCH AND FLIGHT OPERATIONS SUPPORT
INTEGRATION	-	EXPERIMENTS INTO GFL; SPACE STATION MODULES SYSTEM





	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91
GFY																
DDT+E	59	227	362	222	109	73	38	21	41	2	0	0	0	0	0	0
PROD	0	0	10	149	120	75	8	7	7	1	0	0	0	0	0	0
OPER	0	0	4	39	162	133	84	62	63	59	14	0	0	0	0	0
TOTAL	59	227	377	420	391	283	169	142	111	62	14	0	0	0	0	0



	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91
GFY																
DDT+E	59	287	650	872	981	1256	1132	1235	1246	1247	1247	1247	1247	1247	1247	1247
PROD	0	0	10	159	279	356	363	370	378	380	380	380	380	380	380	380
OPER	0	0	4	42	204	337	422	494	547	606	620	620	620	620	620	620
TOTAL	59	287	664	1073	1464	1948	1917	2099	2171	2233	2247	2247	2247	2247	2247	2247

Figure 3-4. Modular Space Station Project Summary Chart (ISS Only)

3.3 RAM PROJECT—PROJECT TOTAL (ISS + GSS) (WBS 1x300)

3.3.1 Summary

The Research Applications Module Project includes the Attached Module, Free Flying Module and Experiment "N" flight equipment. In addition to the flight hardware systems, there is the Experiment Integration, Test Articles, Ground Support Equipment, Facilities, System Support, Project Management, Launch Operations, and Flight Operations required to support the design, development, launch and flight operations.

The total cost of the RAM Project (ISS + GSS) has been estimated to be $2,381 million. This total cost includes $1,855 million for DDT&E, $251 million for production, and $275 million for operations.

Definition

The task definition of this WBS Box is contained in Appendix A.

Cost Assumptions, Ground Rules and Rationale

None in addition to those in Section 2.1.2.

3.3.2 Research Applications Module Project Schedule

The schedule in Figure 3-5 covers design, development, and operations activities required to design, test, produce, and operate the Research Applications Module Project systems. It provides major milestones, key events, and critical actions pertaining to the project and its systems that are vital to the timely execution of the program. Interrelated activities are presented with logic, feasibility, and maximum applications of existing technology and capability.

The schedule provides for a total of 17 Research Applications Modules (RAM's) over the life of the Space Station Program: five Attached Modules to accommodate the Initial Space Station (ISS) phase; nine attached, and three free-flying modules to accommodate the Growth Space Station (GSS) phase. Three major activities are required to achieve the schedule: (1) a supporting research and technology (SRT) program in direct support of the

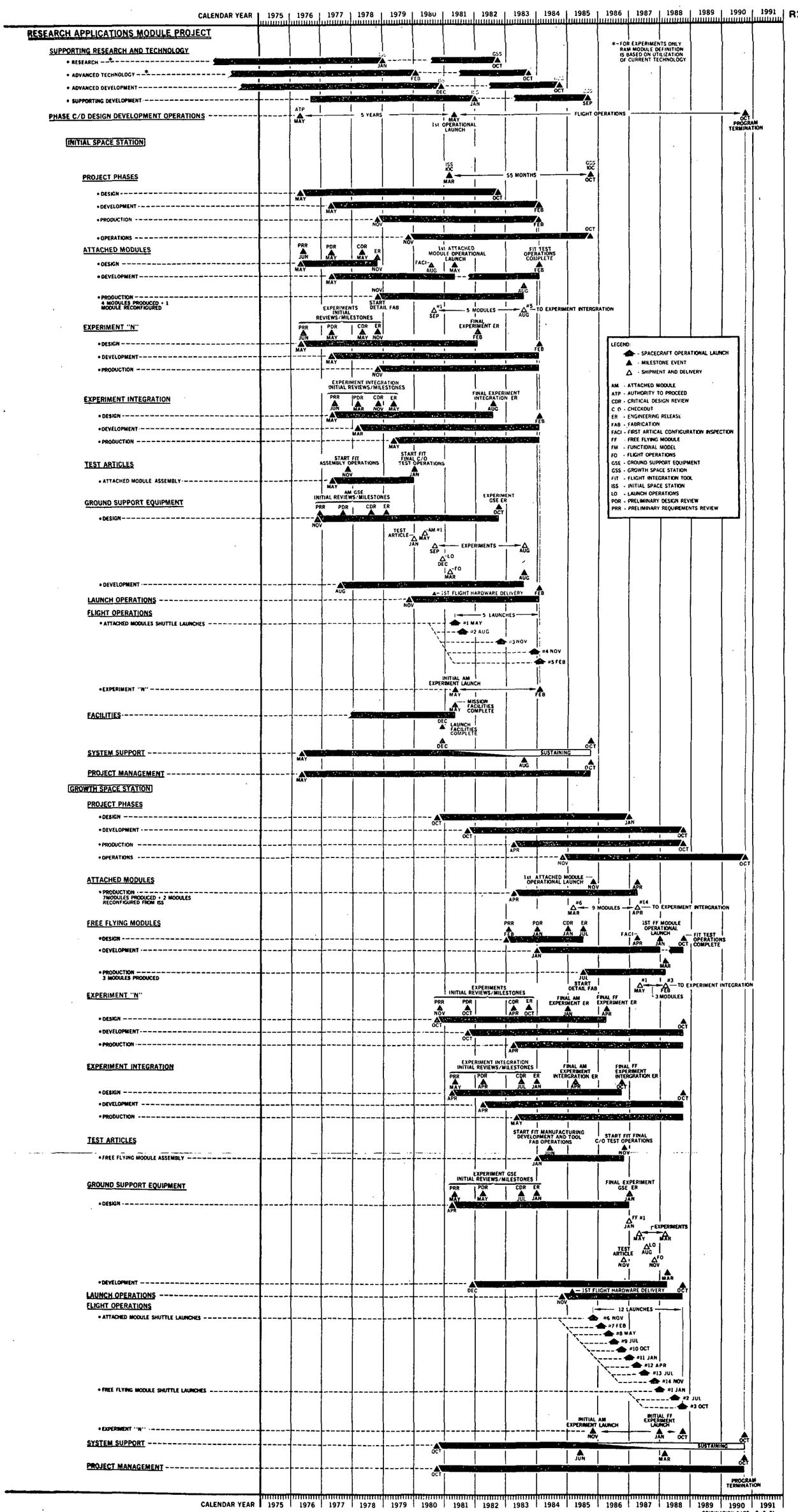


Figure 3-5. RAM Project Schedule

Modular Space Station concept, (2) a combined design, development and operations (Phase C/D), and (3) the development of the Shuttle Program.

Time phasing within the SRT program was established coincident with requirements for definition, design, and development of the project systems. For example, substantial results from research and advanced technology efforts are needed prior to Phase C/D authority to proceed (ATP). Advanced development will contribute to the early Phase C/D and will not be applicable if received too late in Phase D. Supporting development activity decision action will occur several months before final engineering design is complete.

The schedule is based on a Phase C/D design, development and operations ATP in May 1976. The first operational launch occurs 5 years after ATP in May 1981. Nine-and-one-half years of flight operations are complete in October 1990.

The ISS Research Applications Module Project design phase begins at Phase C/D ATP in May 1976, with the start of design of the Attached Modules and Experiment "N" systems.

Design is complete at final engineering release (ER) of the experiment Ground Support Equipment system in October 1982. The development phase is initiated in May 1977, 1 year after design start and is complete at the conclusion of flight integration tool test operations in February 1984. The operations phase begins with the manufacturing detail fabrication start of the first Attached and Experiment "N" RAM in November 1978, and occurs 30 months before the first operational launch in May 1981. The operations phase is complete 54 months after the first operational launch and at the start of GSS flight operations in November 1985.

ISS flight operations begin with the first RAM launch in May 1981. RAM's are delivered to orbit in the Shuttle cargo bay and docked to the Space Station with a single docking operation. RAM launches take place at the rate of two the first year, one the second year and two the third year to complete

the last ISS RAM launch in February 1984, 20 months before the completion of ISS operations. Four of the five RAM Attached Modules required for the ISS flight operations are manufactured and one module is reconfigured and reused.

The GSS Research Applications Module Project design, development, test and evaluation (DDT&E) for the GSS phase begins in October 1980 with design start of the Experiment "N" system. Design is complete at final ER of the experiment Ground Support Equipment system in January 1987. The development phase is initiated in October 1980, 12 months after design start and is complete at the conclusion of Flight Integration Tool test operations in October 1988. The production phase begins with the manufacturing detail fabrication start of the first Attached Module and Experiment "N" in April 1983 and occurs 31 months before the first operational launch in November 1985. The operations phase begins 17 months before the first operational launch and the program operations are complete in October 1990.

The GSS requires 12 Research Applications Modules to achieve the experiment operational flight program. GSS flight operations begin with the first RAM Attached Module launched in November 1985. Eight additional Attached Modules are launched over a 2-year period ending in November 1987. Three free-flying modules are launched over a 9-month period beginning in January 1988 and ending in October 1988, 2 years before the completion of program operations. Seven of the nine RAM Attached Modules required for the GSS flight operations are manufactured, and two modules are reconfigured and reused. Three free-flying modules are manufactured.

3.3.3 Funding Distribution

Cost Methodology

The estimated costs have been developed from summations of cost estimates at subordinate levels. The subordinate cost estimates were developed at one or more levels below those being reported. The costs reported at this level include the cost of integrating the elements at the subordinate levels.

Funding Distribution (ISS + GSS)

Figure 3-6 is a Summary Chart which highlights the relationships of the cost estimates to Technical Characteristics and Schedules. It also presents an overview of the funding allocations, both yearly and cumulatively by Government Fiscal Year (Mid-Year Plot). Funding has been spread based on the Case 534G definition and flight schedule.

RAM PROJECT
ISS + GSS TECHNICAL DESCRIPTION WBS 300

MAJOR HARDWARE

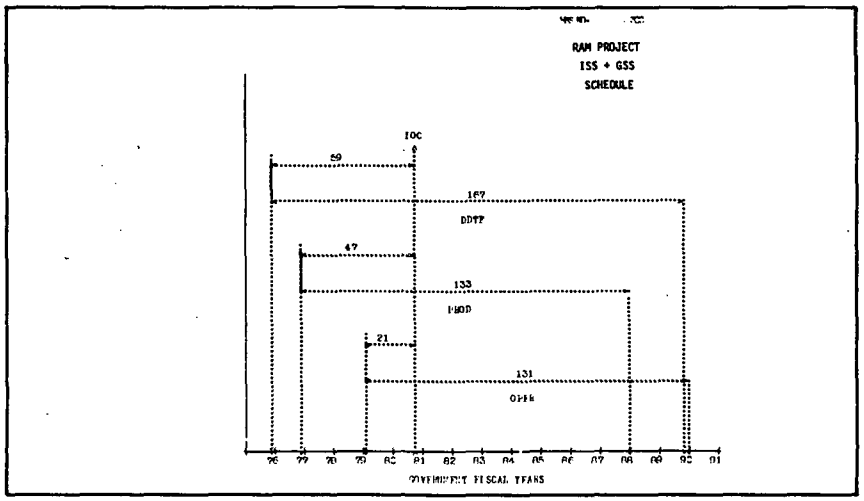
(3) FREE-FLYING MODULES - INTEGRAL PROPULSION, ACS, G AND N

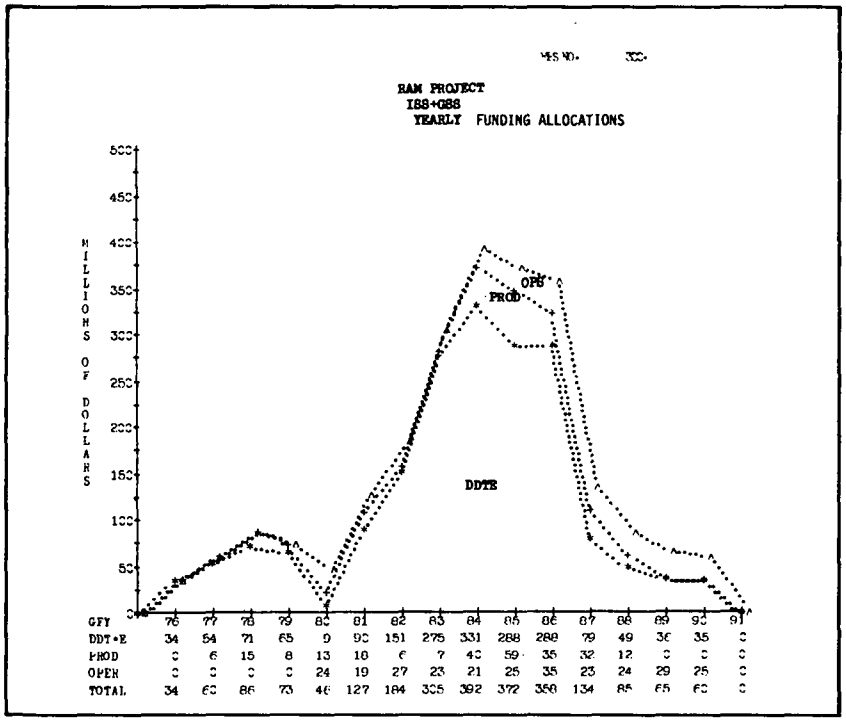
(14) ATTACHED MODULES - (INCLUDING RE-WORK OF 3)

EXPERIMENT "N" - 17 FPE'S - NASA BLUE BOOK, APRIL 1971 - CASE 534G - ACCOMMODATED BY ABOVE MODULES

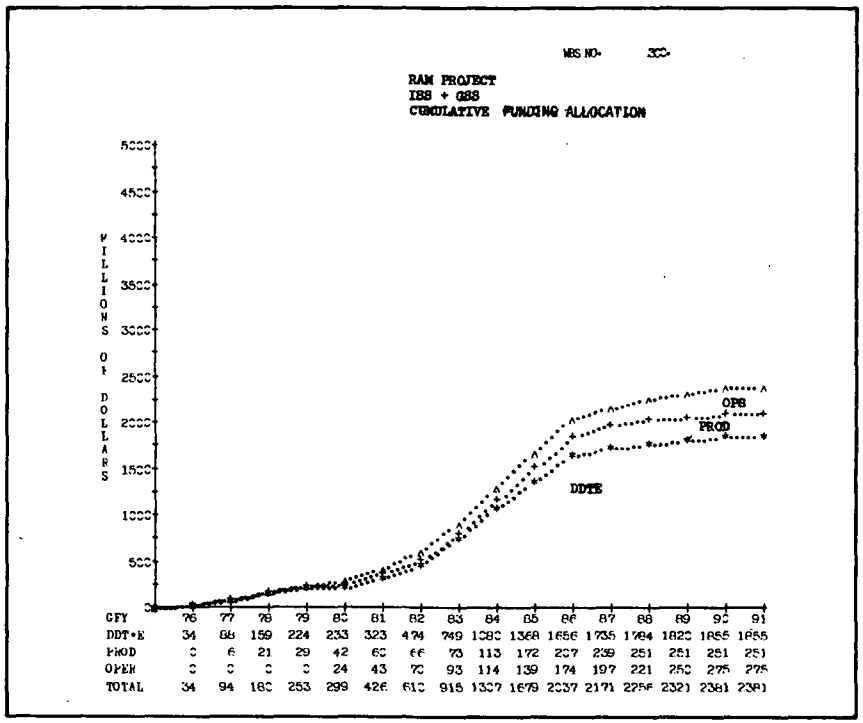
RELATED HARDWARE AND SUPPORT

TEST ARTICLES	-	SUPPORT DEVELOPMENT OF ATTACHED MODULES AND FREE-FLYING MODULES
GSE	-	SUPPORT OF AM'S, FPM'S, AND EXPERIMENTS
FACILITIES	-	MODIFICATIONS FOR DEVELOPMENT, PRODUCTION AND OPERATIONS OF AM'S AND FPM'S
OPERATIONS	-	CONTRACTOR EXPERIMENT SUPPORT
INTEGRATION	-	EXPERIMENTS TO MODULES





GFY	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91
DDT+E	34	54	71	65	9	90	151	275	331	288	280	79	49	36	35	0
PROD	0	6	15	8	13	10	6	7	40	59	35	32	12	0	0	0
OPER	0	0	0	0	24	19	27	23	21	25	35	23	24	29	25	0
TOTAL	34	60	86	73	46	127	184	305	392	372	350	134	85	65	60	0



GFY	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91
DDT+E	34	88	159	224	233	323	474	749	1080	1368	1656	1735	1784	1820	1855	1855
PROD	0	6	21	29	42	52	66	73	113	172	207	239	251	251	251	251
OPER	0	0	0	0	24	43	70	93	114	139	174	197	221	250	275	275
TOTAL	34	94	180	253	299	426	610	915	1307	1679	2037	2171	2256	2321	2381	2381

Figure 3-6. RAM Project Summary Chart

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Section 4

MODULAR SPACE STATION PROJECT

ISS

The Modular Space project is comprised of the following systems:

- Space Station Modules
- Logistics Module
- Integral Experiments
- Experiment Integration
- Facilities
- Ground Support Equipment
- Test Articles
- Launch Operations
- Flight Operations
- Project Management
- System Support

A development and operations schedule, cost estimate, and funding distribution for each of the systems is presented in subsequent sections. Each of the system schedules shows major milestones and design, development and production requirements. The system level activities presented include design engineering, development test, qualification test and vehicle manufacturing, checkout, delivery and operations.

Design, development, production and operation phases are shown separately on system schedules as applicable to identify milestones which impact lower level schedules. Several key design review checkpoints are accomplished during design. These include the Preliminary Requirements Review (PRR) Preliminary Design Review and the Critical Design Review (CDR). Each of these checkpoints has a significant bearing on the Space Station Project systems. The PRR is the earliest technical review of the various concepts

considered and of the concepts selected to meet the mission objectives. The PDR is a formal technical review of the basic design approach for a CEI. The CDR is a formal technical review of the design of a CEI and is conducted before the release of drawings for manufacture.

The system development and qualification test time spans for the Space Station Project are constrained within the program phase durations. The individual system development and qualification testing is performed initially during the test time spans allocated. Integration testing in the Functional Model (FM) and Flight Integration Tool (FIT) is performed first at the subsystem level followed by system level integration testing to demonstrate the capability to operate as a system.

4.1 SPACE STATION MODULES–SYSTEM, TOTAL–ISS ONLY

4.1.1 Summary

The Space Station Modules are the major system of the Modular Space Station Project. Space Station Modules for the ISS phase consists of Power/Subsystems, Crew/Operations and General Purpose Laboratory modules as well as System Integration (system support, non-recurring test operations, module acceptance testing). Excluded are the additional modules and modification equipment required to provide the GSS capability.

Definition

The task definition of this WBS Box is contained in Appendix A.

Cost Assumptions, Ground Rules and Rationale

None in addition to those in Section 2.1.2.

4.1.1.1 Space Station Modules (WBS 2X758)

The Space Station Modules system for the ISS Phase consists of one Power/Subsystems Module, one Crew/Operations Module, one GPL Module, and System Integration.

4.1.1.1.1 Power/Subsystem Module (WBS 2X751)

The Power/Subsystems Module consists of eleven subsystems, as shown in Table 4-1.

4.1.1.1.2 Crew/Operations Module (WBS 2X752)

The Crew/Operations Module consists of ten subsystems, as shown in Table 4-2.

4.1.1.1.3 GPL Module (WBS 2X753)

The GPL Module consists of ten subsystems, as shown in Table 4-3.

4.1.1.1.4 System Integration (WBS 2X759)

System Integration encompasses integration of the modules into an entity known as the Space Station Modules System, and includes system level

Table 4-1

POWER/SUBSYSTEM MODULE

1972 Dollars in Millions

WBS	Title	C	DDT&E	Production	Operations	Total
2X75101	Integration	3	0	25	0	25
2X75102	Structural/ Mechanical	4	29	7	0	37
2X75105	EC&LS	3	29	7	10	47
2X75107	Communications	3	11	3	3	17
2X75123	Propulsion/RCS	3	8	3	3	14
2X75124	Electrical Power	3	84	23	28	135
2X75146	Guidance and Navigation	3	5	1	0	6
2X75147	Data Management	3	14	3	3	20
2X75156	Stabilization and Attitude Control	3	26	3	4	33
2X75157	OCS&FI	3	5	1	1	7
2X75159	Crew Habitability	3	1	0	0	2
	Power Module	3	212	77	53	342

support, nonrecurring test operations, and module acceptance testing. The total cost is estimated to be $226 million.

4.1.2 Costs

Cost Methodology

The estimated costs have been developed from summations of cost estimates at subordinate levels. The subordinate cost estimates were developed at one or more levels below that being reported. The costs reported at this level include the cost of integrating the elements at the subordinate levels.

Table 4-2

CREW/OPERATIONS MODULE

WBS	Title	C	DDT&E	Production	Operations	Total
2X75201	Integration	3	0	24	0	24
2X75202	Structural/ Mechanical	4	8	5	0	13
2X75205	EC&LS	3	41	7	10	58
2X75207	Communications	3	28	7	7	42
2X75223	Propulsion/RCS	3	11	5	5	21
2X75224	Electrical Power	3	5	3	3	11
2X75247	Data Management	3	21	4	4	29
2X75256	Stabilization and Attitude Control	3	2	13	18	33
2X75257	OCS&FI	3	5	1	1	7
2X75259	Crew Habitability	3	11	5	4	20
	Crew Module	3	132	73	53	258

4.1.2.1 Space Station Modules

Cost Estimate

The total cost is estimated to be $1015 millions, as follows:

DDT&E—It is estimated that the DDT&E effort will cost $564 millions, will begin 66 months prior to the milestone launch date of October 1980, and will require 59 months for completion.

Production —It is estimated that the Production effort will cost $294 millions, will begin 43 months prior to the milestone launch date of October 1980, and will require 39 months for completion.

Operations —It is estimated that the Operation effort will cost $156 millions, will begin 28 months prior to the milestone launch date of October 1980, and will continue for 70 months.

Table 4-3

GPL MODULE

WBS	Title	C	DDT&E	Production	Operations	Title
2X75301	Integration	3	0	18	0	18
2X75302	Structural/ Mechanical	4	21	6	0	27
2X75305	EC&LS	3	24	6	10	39
2X75307	Communications	3	0	0	0	0
2X75324	Electrical Power	3	5	3	3	11
2X75339	Exp Sup Eq	3	15	8	7	30
2X75347	Data Management	3	36	7	7	50
2X75356	Stabilization and Attitude Control	3	0	0	0	1
2X75357	OCS&FI	3	6	2	1	9
2X75359	Crew Habitability	3	2	1	1	5
	GPL Module	3	109	50	30	190

Funding Distribution

Figure 4-1 is a Summary Chart which highlights the relationships of the cost estimates to technical characteristics and schedules. It also presents an overview of the funding allocations, both yearly and cumulatively by Government Fiscal Year (Mid-Year Plot). DDT&E funding has been spread using a 70 percent spread function, while production funding was spread at 45 percent, and operations funding is based on a composite spread function.

4.1.2.1.1 Power/Subsystems Module (WBS 2X751)

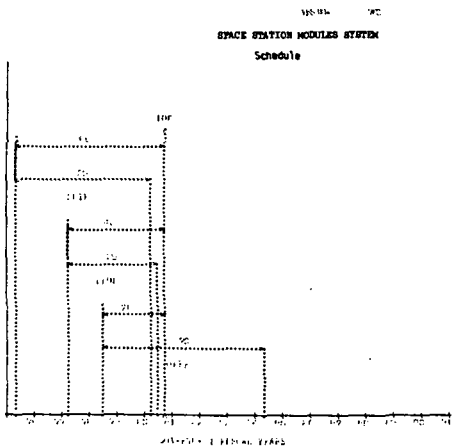
Cost Estimate

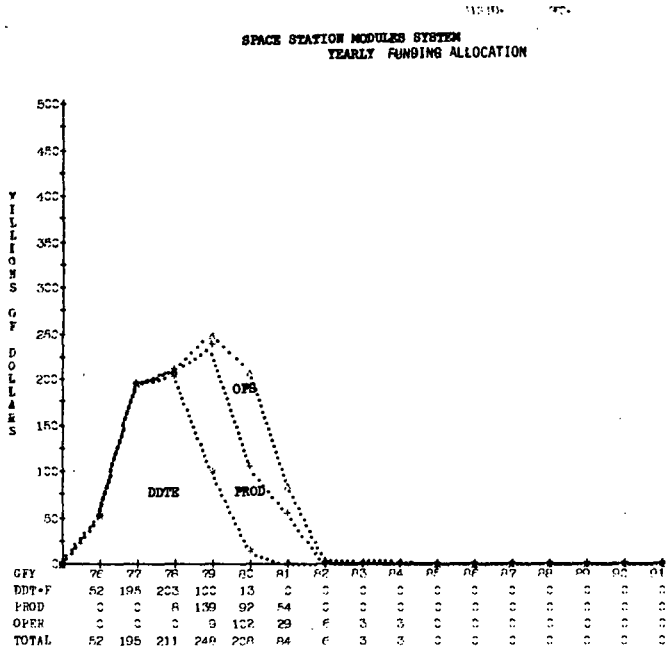
The total cost is estimated to be $342 millions, as follows:

DDT&E—It is estimated that the DDT&E effort will cost $212 millions, will begin 66 months prior to the milestone launch date of October 1980, and will require 57 months for completion.

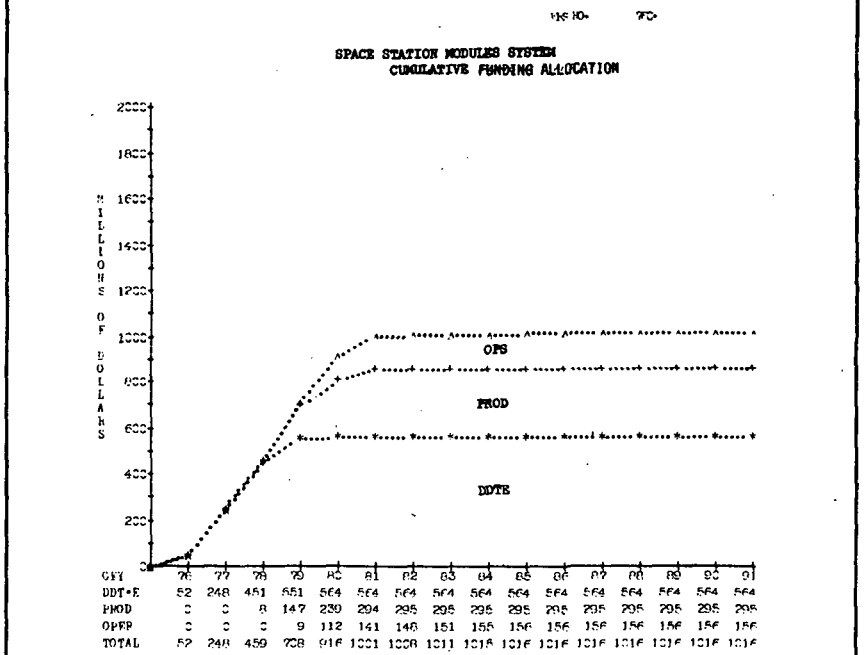
SPACE STATION MODULES SYSTEM (ISS) TECHNICAL DESCRIPTION WBS 2X759

MAJOR DESCRIPTORS	CHARACTERISTICS
Dimensions, Shape, Volume	
3 - 14 Ft. Dia. Cylindrical Modules:	
Power/Subsystems Module	58 Ft. Long; 3780 Cu.Ft Volume; Launch Weight - 18,435 Pounds; Operational Weight - 23,917 Pounds
Crew/Operations Module	45 Ft. Long; 5480 Cu.Ft.Volume; Launch Weight - 17,231 Pounds; Operational Weight - 24,105 Pounds
OPF Module	45 Ft. Long; 5480 Cu.Ft. Volume; Launch Weight - 17,602 Pounds; Operational Weight - 26,012 Pounds
Total - 3 Modules	14,740 Cu.Ft. Volume; Launch Weight - 53,468 Pounds; Operational Weight - 74,034 Pounds
Docking Ports/ Airlocks	
Radial Docking Ports	6
End Docking Ports	6
IVA Airlocks	7
EVA Airlock	1
Scientific Airlock	1
Subsystems	
Structural/Mechanical	Data Management
17 KWe Solar/Battery Electrical Power	Crew Habitability
Environmental Control/Life Support	Stabilization and Attitude Control
Propulsion/Reaction Control	Onboard Checkout and Fault Isolation
Guidance and Navigation	Experiment Support Equipment
Communications	Installation and Integration
Technology	Generally Current
Additional Cost Considerations	
Size/Shape/Materials/Weight	Commonality
Fabrication/Assembly Methods	Maintainability
Tooling Requirements	Test Philosophy
Quantities - Subsystems/Flight Articles	Complexity/Workability





FY	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91
DDT+E	52	195	203	100	13	0	0	0	0	0	0	0	0	0	0	0
PROD	0	0	8	139	92	54	0	0	0	0	0	0	0	0	0	0
OPER	0	0	0	9	102	29	6	3	3	0	0	0	0	0	0	0
TOTAL	52	195	211	248	208	84	6	3	3	0	0	0	0	0	0	0



FY	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91
DDT+E	52	248	451	551	564	564	564	564	564	564	564	564	564	564	564	564
PROD	0	0	8	147	239	294	295	295	295	295	295	295	295	295	295	295
OPER	0	0	0	9	112	141	148	151	155	156	156	156	156	156	156	156
TOTAL	52	248	459	708	916	1001	1008	1011	1018	1016	1016	1016	1016	1016	1016	1016

Figure 4-1. Space Station Modules Summary Chart (ISS Only)

Production —It is estimated that the Production effort will cost $77 millions, will begin 43 months prior to the milestone launch date of October 1980, and will require 37 months for completion.

Operations —It is estimated that the Operation effort will cost $53 millions, will begin 28 months prior to the milestone launch date of October 1980, and will continue for 35 months.

Funding Distribution

Figure 4-2 is a Summary Chart which highlights the relationships of the cost estimates to Technical Characteristics and Schedules. It also presents an overview of the funding allocations, both yearly and cumulatively by Government Fiscal Year (Mid-Year Plot). DDT&E funding has been spread using a 70-percent spread function, while production funding was spread at 50 percent, and operations funding is based on a composite spread function.

4.1.2.1.2 Crew/Operations Module (WBS 2X752)

Cost Estimate

The total cost is estimated to be $258 millions, as follows:

DDT&E—It is estimated that the DDT&E effort will cost $132 millions, will begin 65 months prior to the milestone launch date of October 1980, and will require 57 months for completion.

Production —It is estimated that the Production effort will cost $73 millions, will begin 42 months prior to the milestone launch date of October 1980, and will require 37 months for completion.

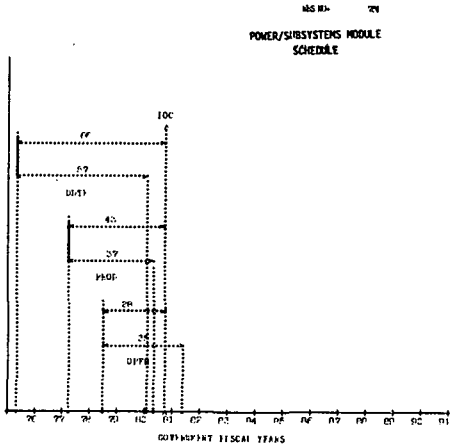
Operations —It is estimated that the Operations effort will cost $53 millions, will begin 27 months prior to the milestone launch date of October 1980, and will continue for 35 months.

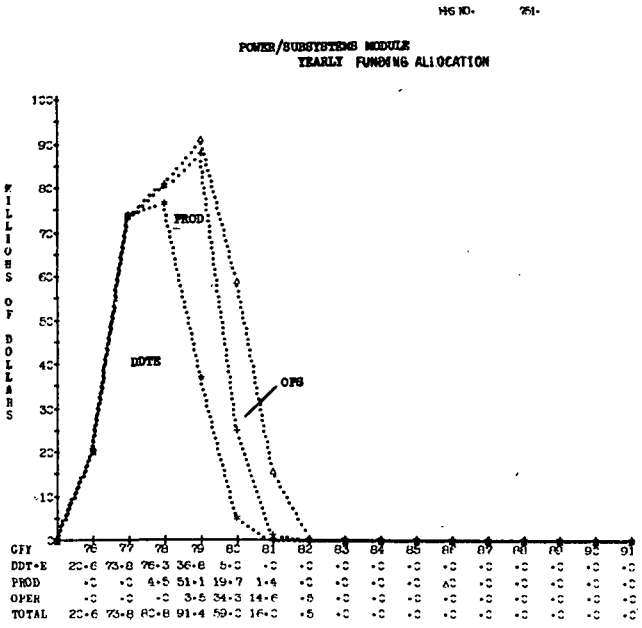
Funding Distribution

Figure 4-3 is a Summary Chart which highlights the relationships of the cost estimates to technical characteristics and schedules. It also presents an overview of the funding allocations, both yearly and cumulatively by Government Fiscal Year (Mid-Year Plot). DDT&E funding has been spread using

POWER/SUBSYSTEMS MODULE (ISS) TECHNICAL DESCRIPTION WBS 5X751

MAJOR DESCRIPTORS	CHARACTERISTICS
Dimensions, Shape, Volume	14 Ft.Dia. Cylinder, 98 Ft.Long -Overall Launch Weight - 10,435 Pounds Operational Weight - 23,917 Pounds Volume - 3760 Cu.Ft.
Pressurized Compartment	14 Ft.Dia. X 30.5 Ft.Long
40-inch Dia. Tunnel and Solar Array Deployment Mechanism	25 Ft. Long
End Docking Ports (2)	2.5 Ft. Long
Docking Ports/Airlocks	
Radial Docking Ports	3
End Docking Ports	2
IVA Airlocks	4
Subsystems	
17 KWe Solar Array/Battery Electrical Power	5300 Ft^2 Externally Stowed Solar Array;Astromast Deployment Concept
Structural Mechanical	
Environmental Control/Life Support	
Propulsion/Reaction Control	
Guidance and Navigation	
Communications	
Data Management	
Crew Habitability	
Stabilization and Attitude Control	
Onboard Checkout and Fault Isolation	
Installation and Integration	
Technology	Generally Current; Some Technology Development required for the Electrical Power Subsystem, Communications Subsystem, and Data Management Subsystem
Additional Cost Considerations	
Size/Range/Materials/Weight	Commonality / Maintainability
Fabrication/Assembly Methods	Test Philosophy / Complexity/Workability
Tooling Requirements	Quantity - Subassemblies / Quantity - Subsystems





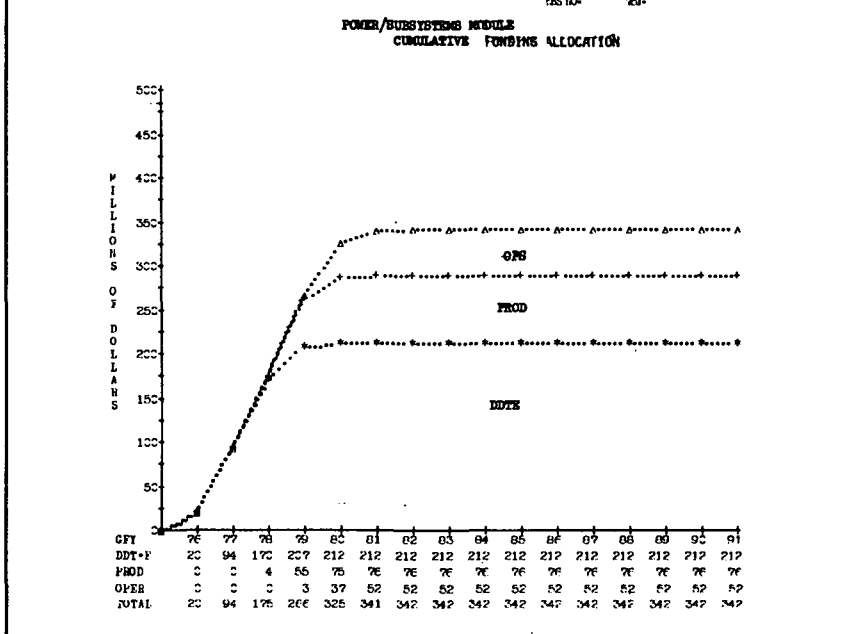
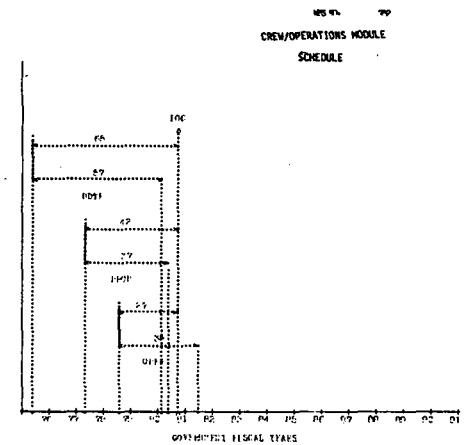
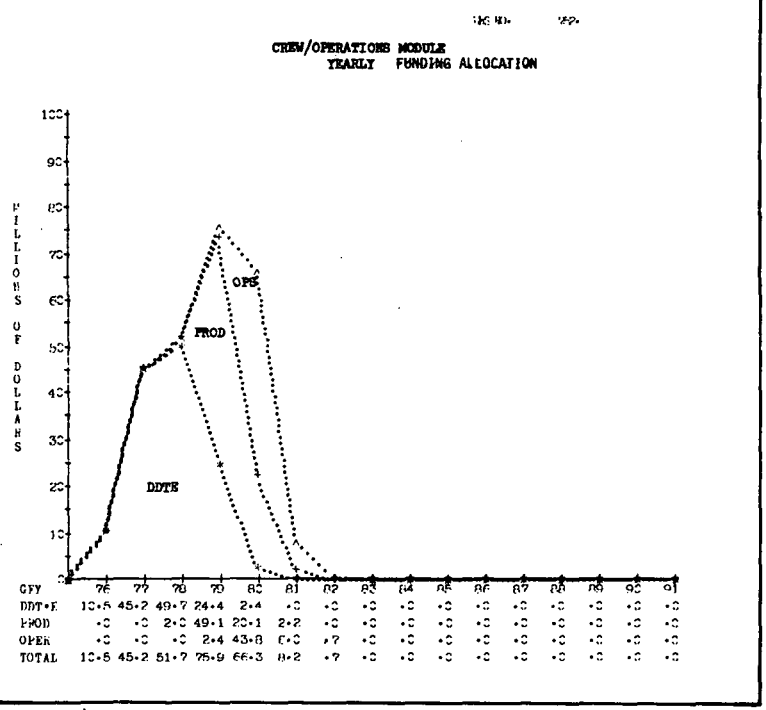


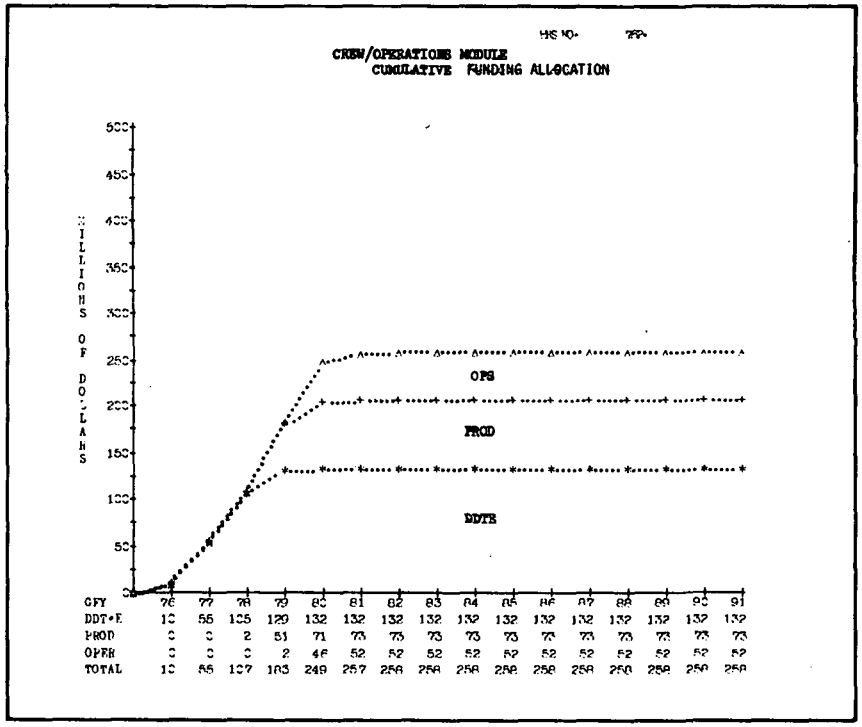
Figure 4-2. Power/Subsystems Module Summary Chart (ISS Only)

CREW/OPERATIONS MODULE (ISS)	TECHNICAL DESCRIPTION	WBS 5X752
MAJOR DESCRIPTORS	CHARACTERISTICS	
Dimensions, Shape, Volume	14 Ft. Dia. Cylinder, 45 Ft. Long Overall Launch Weight - 17,231 Pounds Operational Weight - 24,105 Pounds Volume - 5480 Cu.Ft.	
Crew Quarters (6)	200 Cu.Ft. Each	
Hygiene Compartments (2)	Each Has Shower and Waste Management	
Wardroom	Includes Operations Center and Galley	
Antennas (3)	High Gain	
Docking Ports/Airlocks		
Radial Docking Ports	3	
End Docking Ports	2	
IVA Airlocks	2	
Subsystems		
Crew Habitability	Structural/Mechanical	
Environmental Control/ Life Support	Data Management	
Propulsion/Reaction Control	Stabilization and Attitude Control	
Communications	Onboard Checkout and Fault Isolation	
Electrical Power	Installation and Integration	
Technology	Generally Current; Some Technology Development required for the Crew Habitability Subsystem	
Additional Cost Considerations		
Size/Shape/Materials/Weight	Commonality	Maintainability
Fabrication/Assembly Methods	Test Philosophy	Complexity/Workability
Tooling Requirements	Quantity - Subassemblies	Quantity - Subsystems





GFY	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91
DDT+E	10.5	45.2	49.7	24.4	2.4	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
PROD	.0	.0	2.0	49.1	20.1	2.2	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
OPER	.0	.0	.0	2.4	43.8	0.0	.7	.0	.0	.0	.0	.0	.0	.0	.0	.0
TOTAL	10.5	45.2	51.7	75.9	66.3	8.2	.7	.0	.0	.0	.0	.0	.0	.0	.0	.0



GFY	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91
DDT+E	10	55	105	129	132	132	132	132	132	132	132	132	132	132	132	132
PROD	0	0	2	51	71	73	73	73	73	73	73	73	73	73	73	73
OPER	0	0	0	2	46	52	52	52	52	52	52	52	52	52	52	52
TOTAL	10	55	107	183	249	257	256	256	256	256	256	256	256	256	256	256

Figure 4-3. Crew/Operations Module Summary Chart (ISS Only)

a 70 percent spread function, while production funding was spread at 50 percent, and operations funding is based on a composite spread function.

4.1.2.1.3 GPL Module (WBS 2X753)

Cost Estimate

The total cost is estimated to be $190 millions, as follows:

DDT&E—It is estimated that the DDT&E effort will cost $109 millions, will begin 64 months prior to the milestone launch date of October 1980, and will require 57 months for completion.

Production —It is estimated that the production effort will cost $50 millions, will begin 41 months prior to the milestone launch date of October 1980, and will require 37 months for completion.

Operations —It is estimated that the operation effort will cost $30 millions, will begin 26 months prior to the milestone launch date of October 1980, and will continue for 35 months.

Funding Distribution

Figure 4-4 is a Summary Chart which highlights the relationships of the cost estimates to technical characteristics and schedules. It also presents an overview of the funding allocations, both yearly and cumulatively by Government Fiscal Year (Mid-Year Plot). DDT&E funding has been spread using a 70 percent spread function, while production funding was spread at 50 percent, and operations funding is based on a composite spread function.

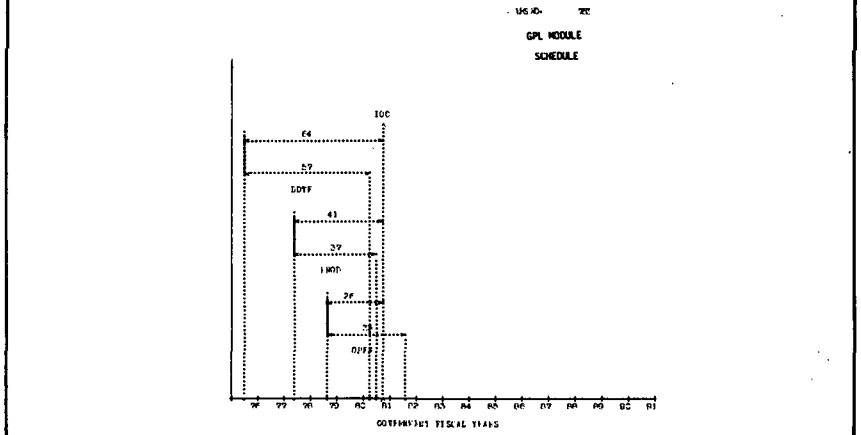
4.1.2.1.4 System Integration (WBS 2X759)

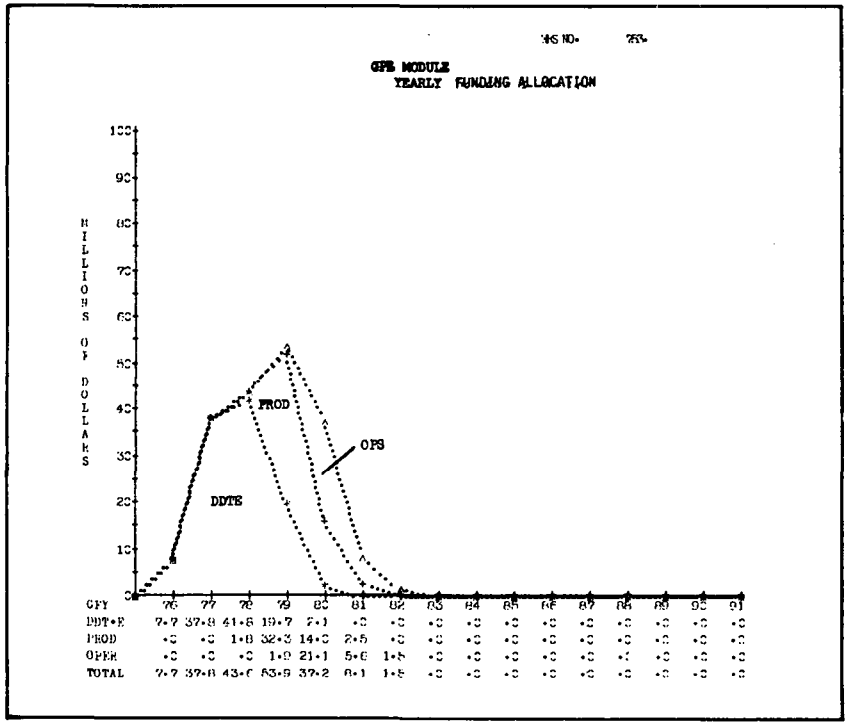
Cost Estimate

The total cost is estimated to be $226 millions, as follows:

DDT&E—It is estimated that the DDT&E effort will cost $111 millions, will begin 66 months prior to the milestone launch date of October 1980, and will require 58 months for completion.

GPL MODULE (ISS)	TECHNICAL DESCRIPTION	WBS 2X753
MAJOR DESCRIPTORS	CHARACTERISTICS	
Dimensions, Shape, Volume	14 Ft. Dia. Cylinder, 45 Ft. Long Overall Launch Weight - 17,802 Pounds Operational Weight - 26,012 Pounds Volume - 5480 Cu.Ft.	
Facilities	Docking Ports/Airlocks	
Electrical/Electronic Laboratory	Radial Docking Ports	0
Experiment and Test Isolation	End Docking Ports	2
Mechanical Sciences Laboratory	IVA Airlocks	1
Hard Data Processing	EVA Airlock	1
Optics Facility	Scientific Airlock	1
Additional Features		
Secondary Control Console	Backup for Primary Control Console; Support of RAMS	
Depressurization	Complete Chamber for Vacuum Experiments	
Experiments	Accommodates all Integral Experiments	
Subsystems		
Experiment Support Equipment	Structural Mechanical	
Environmental Control/ Life Support	Data Management	
Communications	Stabilization and Attitude Control	
Electrical Power	Onboard Checkout and Fault Isolation	
Crew Habitability	Installation and Integration	
Technology	Generally Current; Some Technology Development required for the Experiment Support Equipment, Data Management, and Communications Subsystems	
Additional Cost Considerations		
Size/Shape/Materials/Weight	Commonality	Maintainability
Fabrication/Assembly Methods	Test Philosophy	Complexity/Workability
Tooling Requirements	Quantity - Subassemblies	Quantity - Subsystems





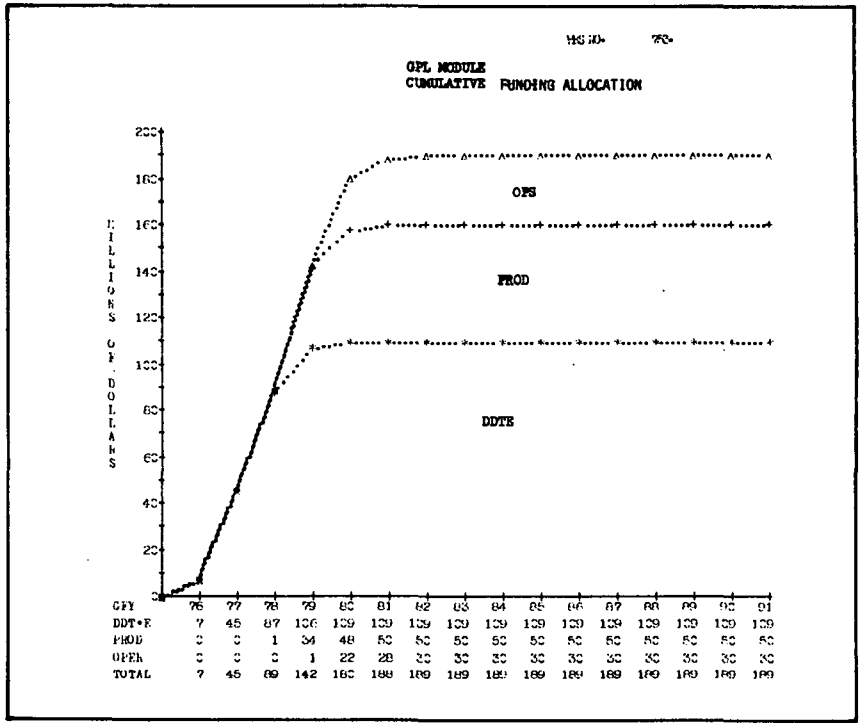


Figure 4-4. GPL Module Summary Chart (ISS Only)

Production —It is estimated that the Production effort will cost $94 millions, will begin 36 months prior to the milestone launch date of October 1980, and will require 40 months for completion.

Operations —It is estimated that the Operation effort will cost $20 millions, will begin 26 months prior to the milestone launch date of October 1980, and will continue for 68 months.

4.1.3 Schedule

The Space Station Modules system design engineering starts at phase C/D ATP. Engineering release occurs 30 months after ATP and 30 months before the first Space Station Module operational launch. Test Article design is complete in April 1977 (see Figure 4-5).

The development phase ATP is October 1976 one year after design start. The development phase will require 4 years and is complete at first operational launch. Test operations begin with development and tool fabrication using the Flight Integration Tool, and continue to February 1980 to verify interface software and procedures final checkout prior to the start of the operational vehicle final integrated checkout. The Flight Integration Tool is then used for factory integration and checkout of new and modified equipment to be installed in orbit. This continues to October 1984 to support carry-on integral experiments.

Production span time for the Space Station Modules system is a 6 months period, February to August 1980. Final integrated checkout of the Power/Subsystems Module, the Crew/Operations Module and the General Purpose Module as an integrated unit is accomplished at the factory before the individual modules are delivered to the launch site. Delivery of the respective modules takes place in August, September and October 1980, to prepare for launches in October, November, and December 1980.

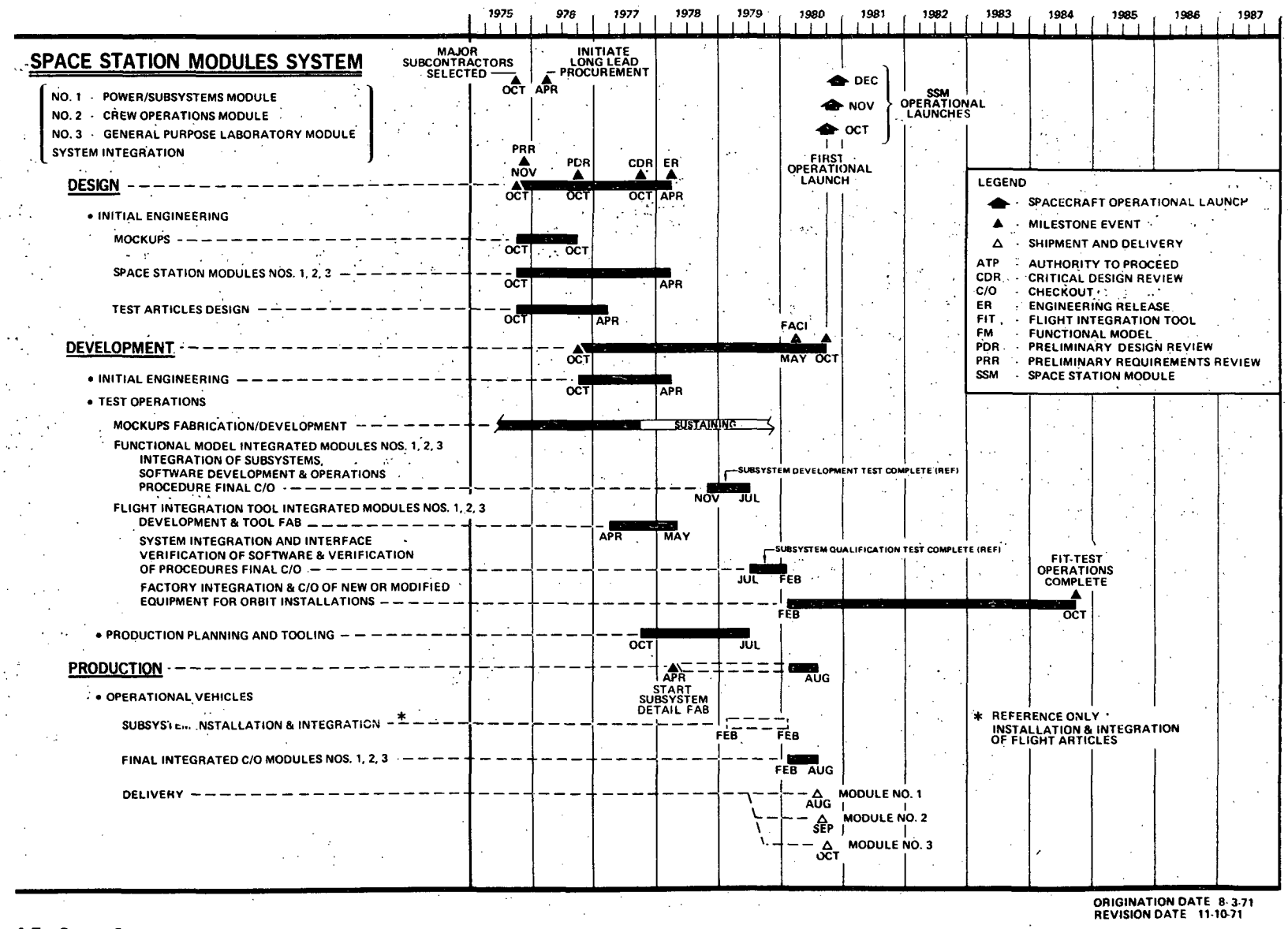


Figure 4-5. Space Station Modules System Schedule (ISS Only)

4.2 LOGISTICS MODULE–ISS ONLY (WBS 2X761)

4.2.1 Summary

The Logistics Module (Log M) is a system utilized for Shuttle transport of cargo (exclusive of crewmen) and in-orbit storage of consumables in support of the Modular Space Station Program during the ISS phase.

Four Logistic Modules will be required. At least one remains in orbit, docked to the ISS, at all times after ISS activation.

Definition

The task definition of this WBS Box is contained in Appendix A.

Cost Assumptions, Ground Rules, and Rationale

None in addition to those in Section 2.1.2.

4.2.2 Cost

4.2.2.1 Cost Methodology

The estimated costs have been developed from summations of cost estimates at subordinate levels. The subordinate cost estimates were developed at one or more levels below that being reported. The costs reported at this level include the cost of integrating the elements at the subordinate levels.

4.2.2.2 Cost Estimate

The total cost is estimated to be $86 millions, as follows:

DDT&E–It is estimated that the DDT&E effort will cost $42 millions, will begin 52 months prior to the milestone launch date of October 1980, and will require 49 months for completion.

Production–It is estimated that the production effort will cost $37 millions, will begin 34 months prior to the milestone launch date of October 1980, and will require 32 months for completion.

Operations —It is estimated that the operation effort will cost $8 millions, will begin 13 months prior to the Milestone Launch Date of October 1980, and will continue for 57 months.

4.2.2.3 Funding Distribution

Figure 4-6 is a Summary Chart which highlights the relationships of the cost estimates to technical characteristics and schedules. It also presents an overview of the funding allocations, both yearly and cumulatively by Government Fiscal Year (Mid-Year Plot). DDT&E funding has been spread using a 50 percent spread function, while production funding was spread at 40 percent, and operations funding is based on a composite spread function.

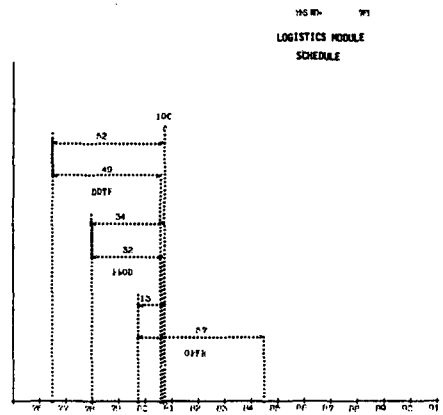
4.2.3 Schedule

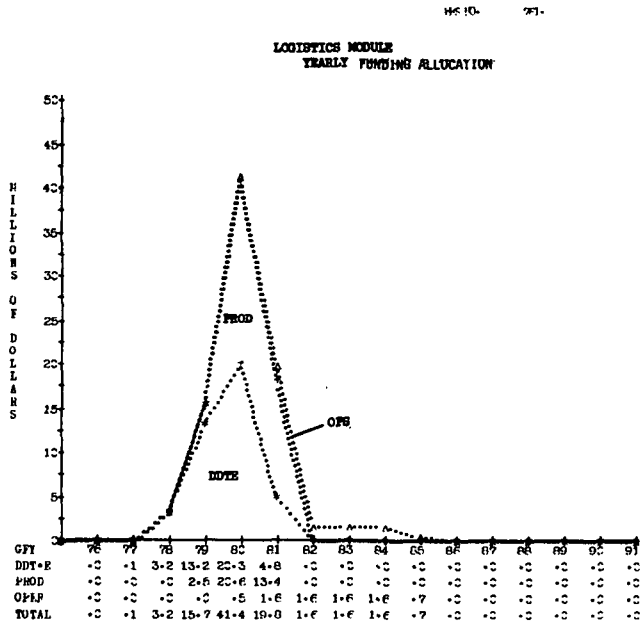
The Logistics Module system includes all of the effort to design, develop, produce and deliver four Logistics Modules (LOG M). The LOG M system level activities shown on the system schedule include design engineering, development test, qualification test, and deliveries as well as operational vehicle manufacturing and checkout including installation and integration. Major milestones, key events, and critical actions identified are related to project level requirements (see Figure 4-7).

The Logistics Module system design engineering starts in December 1976 and continues for a period of 22 months. Engineering release (ER) occurs in October 1978 and is coincident with the start of operational vehicle subassembly. Critical design review (CDR) is complete 2 months before ER at the beginning of detail fabrication for operational vehicles. First article configuration inspection (FACI) is performed at the time of delivery of the first flight hardware in April 1980.

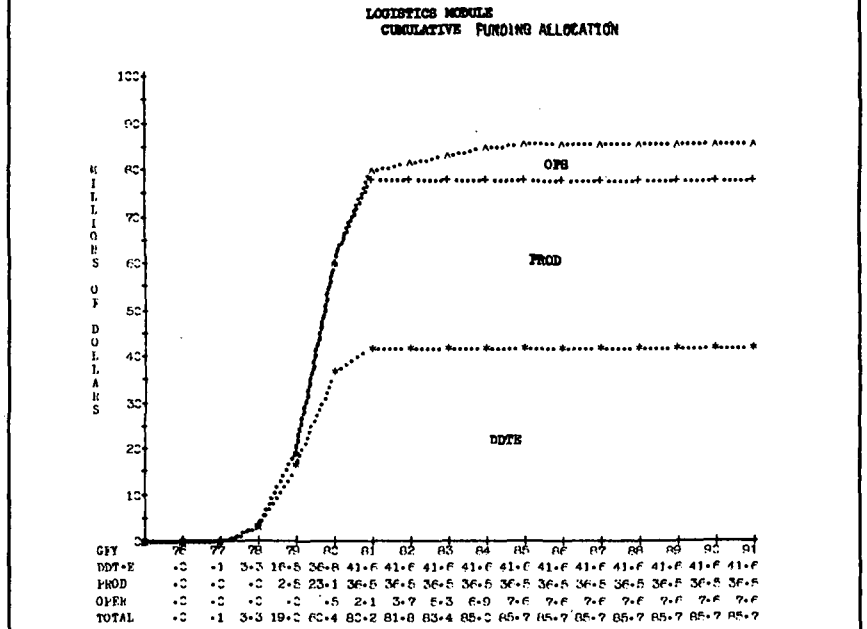
The development phase ATP is September 1977, 10 months after design start. Forty months are required to complete the development phase by January 1981. Test operations begin with use of the Development Fixture (DF) for development and tool fabrication in January 1978, and are complete with the operations procedures final checkout using the Functional Model (FM) in September 1979.

LOGISTICS MODULE SYSTEM (ISS)	TECHNICAL DESCRIPTION	WBS 2X761
MAJOR DESCRIPTORS	CHARACTERISTICS	
Dimensions, Shape, Volume	14 Ft. Dia. Cylinder, 28 Ft. Long Volume - 3500 Cu.Ft.	
Total Weight - Empty	5969 Pounds	
Cargo Capability	14,031 Pounds	
Total Launch Weight (Loaded)	20,000 Pounds	
Quantity	4 - Modules	
Compartments		
Pressurized	Special Cargo Area; Palletized Cargo Area;Liquid/Gas Cargo Area	
Unpressurized	Propellant Cargo Tankage; High Pressure Gaseous Nitrogen Tanks	
Docking Ports/Airlocks		
End Docking Ports	2	
EVA Airlock	1 (2-Man); Also serves as egress/ingress from Orbiter to Logistics Module and Space Station	
Subsystems	No Active Subsystems; All Subsystem Requirements supplied either by Orbiter or Space Station	
Technology	Current	
Additional Cost Considerations		
Size/Shape/Materials/Weight	Commonality	
Fabrication/Assembly Methods	Maintainability	
Tooling Requirements	Test Philosophy	
Quantities - Subsystems/Flight Articles	Refurbishment	
Complexity/Workability		





FY	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91
DDT&E	.0	.1	3.2	13.2	22.3	4.8	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
PROD	.0	.0	.0	2.6	20.6	13.4	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
OPER	.0	.0	.0	.0	.5	1.6	1.6	1.6	1.6	.7	.0	.0	.0	.0	.0	.0
TOTAL	.0	.1	3.2	15.7	41.4	19.8	1.6	1.6	1.6	.7	.0	.0	.0	.0	.0	.0



FY	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91
DDT&E	.0	.1	3.3	16.5	38.8	41.6	41.6	41.6	41.6	41.6	41.6	41.6	41.6	41.6	41.6	41.6
PROD	.0	.0	.0	2.5	23.1	36.5	36.5	36.5	36.5	36.5	36.5	36.5	36.5	36.5	36.5	36.5
OPER	.0	.0	.0	.0	.5	2.1	3.7	5.3	6.9	7.6	7.6	7.6	7.6	7.6	7.6	7.6
TOTAL	.0	.1	3.3	19.0	62.4	80.2	81.8	83.4	85.0	85.7	85.7	85.7	85.7	85.7	85.7	85.7

Figure 4-6. Logistics Module Summary Chart (ISS Only)

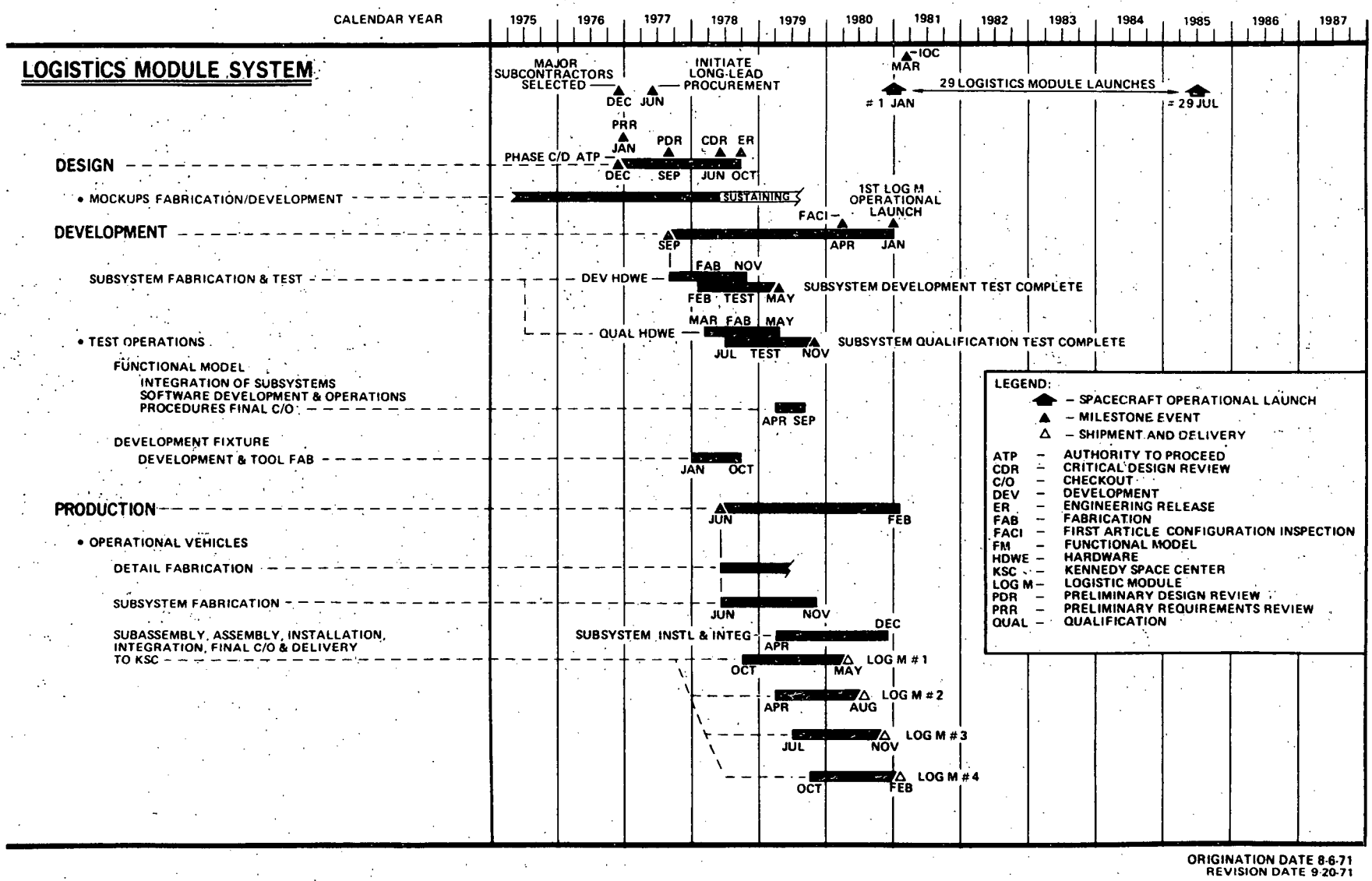


Figure 4-7. Logistics Module System Schedule (ISS Only)

Production of operational vehicles begins with detail fabrication for subsystems in June 1978. Subassembly start is in October 1978, followed by assembly and installation and integration of subsystems starting in April 1979. Final checkout and delivery of first production vehicle is complete in May 1980, 8 months before the first Logistics Module launch. LOG M's 2, 3, and 4 are completed and delivered 3 months apart. The last delivery is February 1981.

During the GSS phase two of the Logistics Modules are reconfigured to Crew Cargo Modules and two new Crew Cargo Modules are manufactured for a total of four Crew Cargo Modules to be used during GSS.

4.3 INTEGRAL EXPERIMENTS—ISS ONLY (WBS 2X999)

4.3.1 Summary

Integral Experiments consist of those individual FPE's from the Baseline Experiment Program 534 G which are integral to the Space Station. Experiment support equipment required to adapt the experiment to the Space Station Modules is not included. This support equipment will be provided under the Experiment Integration WBS box. A summary of the individual FPE costs is furnished in Table 4-4.

Definition

The task definition of this WBS Box is contained in Appendix A.

Cost Assumptions, Ground Rules and Rationale

None in addition to those in Section 2.1.2.

4.3.2 Cost

4.3.2.1 Cost Methodology

The estimated costs have been developed from summations of cost estimates at subordinate levels. The subordinate cost estimates were developed at one or more levels below that being reported. The costs reported at this level include the cost of integrating the elements at the subordinate levels.

4.3.2.2 Cost Estimate

The total cost is estimated to be $156 millions, all of which is DDT&E. It is estimated that the DDT&E effort will begin 66 months prior to the milestone launch date of October 1980, and will require 108 months for completion.

4.3.2.3 Funding Distribution

Figure 4-8 is a Summary Chart which highlights the relationships of the cost estimates to technical characteristics and schedules. It also presents an overview of the funding allocations, both yearly and cumulatively by Government Fiscal Year (Mid-Year Plot). DDT&E funding has been spread using a 50 percent spread function.

Table 4-4

FPE COSTS FOR INTEGRAL EXPERIMENTS, EXPERIMENT GSE AND EXPERIMENT INTEGRATION

(ISS ONLY)

(1972 dollars in millions)

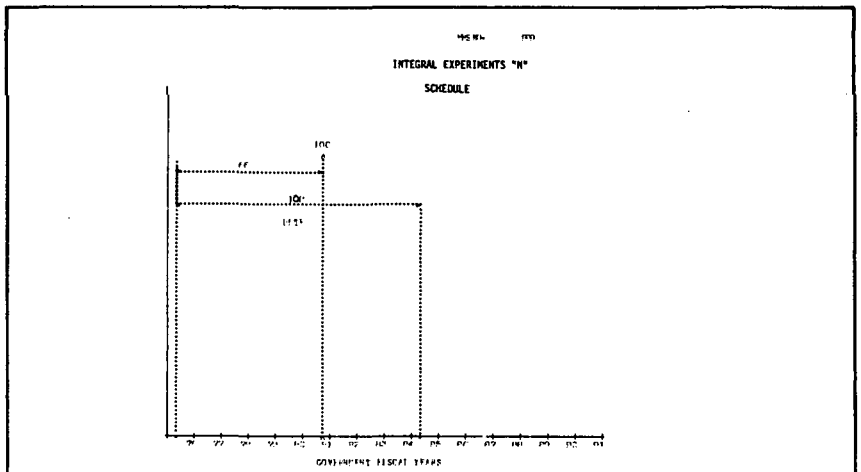
FPE No.		Integral Experiments	Experiment GSE	Experiment Integration
LS-1A	(Minimal Medical Research Facility)	39.98	9.39	13.03
T-4B	(Medium Duration Tests)	2.93	0.69	2.04
T-4A	(Long Duration System Tests)	1.42	0.34	1.22
T-4C	(Short Duration Tests)	3.12	0.72	3.18
P-1D	(Thick Material Meteoroid Penetration)	0.92	0.21	0.61
P-4B	(Flame Chemistry and Laser Experiments)	6.40	1.51	3.05
T-1B	(Contamination Monitor Pkg.)	2.07	0.48	4.64
T-1A	(Contamination Experimental Pkg.)	5.87	1.38	4.64
T-3A	(Astronaut Maneuver Unit)	6.22	1.46	4.07
P-4A	(Airlock and Boom Experiments)	8.89	2.09	7.74
MS-3A	(Crystal Growth, Biological and Physical Processes)	14.99	3.52	13.23
MS-3B	(Crystal Growth from Vapor)	1.98	0.47	1.79
MS-3C	(Controlled Density Materials)	1.67	0.28	0.86
MS-3D	(Liquid and Glass Processing)	0.24	0.06	0.32
MS-3E	(Supercooling and Homogeneous Nucleation)	0.55	0.13	0.49
T-5A	(Initial Flight, Teleoperator)	20.17	4.74	7.90
P-3C	(Plastic/Nuclear Emulsions)	3.22	0.76	1.06
P-1B	(Cometary Physics)	4.38	1.03	1.22
P-1C	(Meteoroid Science)	4.60	1.06	1.63
P-1E	(Small Astronomy Telescopes)	7.50	1.77	5.09
P-4C	(Test Chamber Experiments)	10.34	2.43	4.47
P-1A	(Atmospheric and Magneto)	8.71	2.05	12.21
		155.69	36.55	94.77

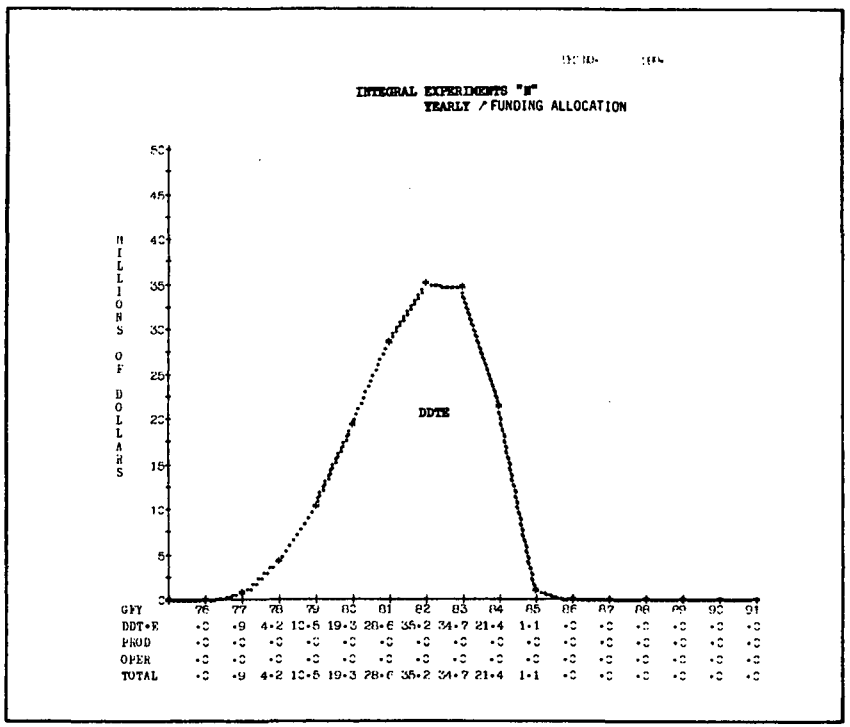
INTEGRAL EXPERIMENT "N'S" (ISS) TECHNICAL DESCRIPTION WBS 2X999

Portions of 22 FPE's have been identified as being accommodated within the GFL Module of the Space Station.

These experiments have been defined in NASA's Blue Book dated April 1971.

Experiment Costs and Development times are those indicated in the Blue Book.





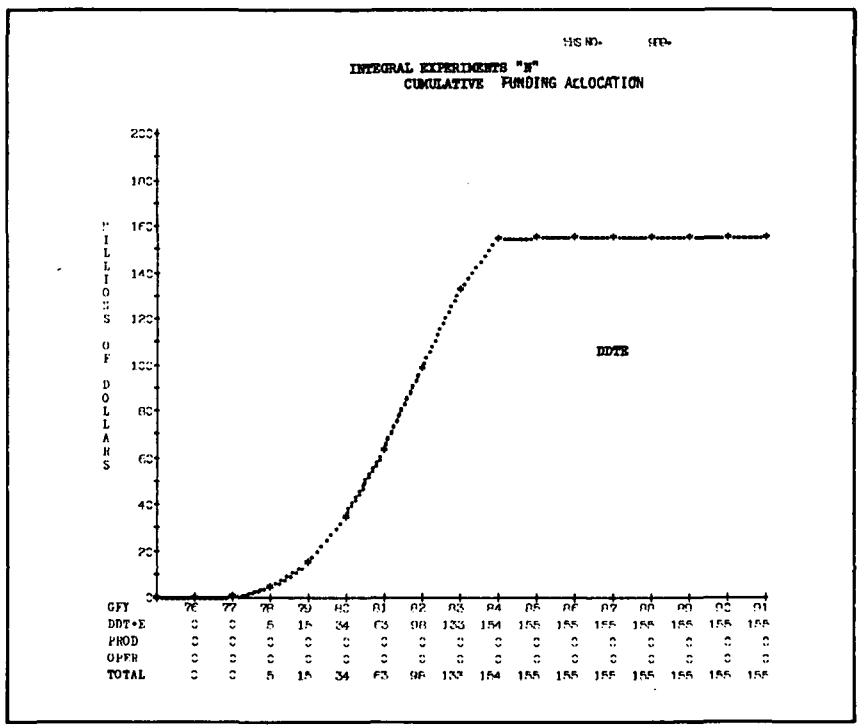


Figure 4-8. Integral Experiment Summary Chart (ISS Only)

4.3.3 Schedule

The Integral Experiment System consists of those individual Functional Program Elements (FPE's) from the Baseline Experiment Program which are integral to the Space Station. Twenty-two (22) FPE's have been identified for launch aboard the Space Station and Logistics modules during the 5 years of ISS operations (see Figure 4-9).

The Integral Experiment System begins with Experiment Design at program phase C/D ATP in October 1975. Engineering release for the first three FPE's, which are carried into orbit in the Space Station, is April 1978. Final ER for carry-on experiment FPE's, those carried into orbit in Logistics modules and off-loaded to the Space Station in orbit, is April 1982. Critical Design Review (CDR's) occur 2 months before ER for individual FPE's. Design is complete at ER and development continues to the point of FPE launch onboard a LOG M.

The operations phase begins with the start of detail fabrication for the first FPE in April 1978. Fabrication, subassembly, assembly installation, integration and checkout occur in the operations between start of operations and the operational launch. Time from the operational launch to the end of operations is on orbit time. FPE's are returned to earth in Logistics modules at experiment termination. The first group of FPE's is launched onboard the Space Station in October 1981. All other FPE's are transported to the Space Station in Logistics modules. The shortest duration of an FPE on orbit is 6 months. Five experiment FPE's launched in October 1983 are on orbit at the end of the ISS phase in October 1985 and remain on orbit to the completion of the GSS phase 10 year program. Additional FPE's are launched during the GSS Phase.

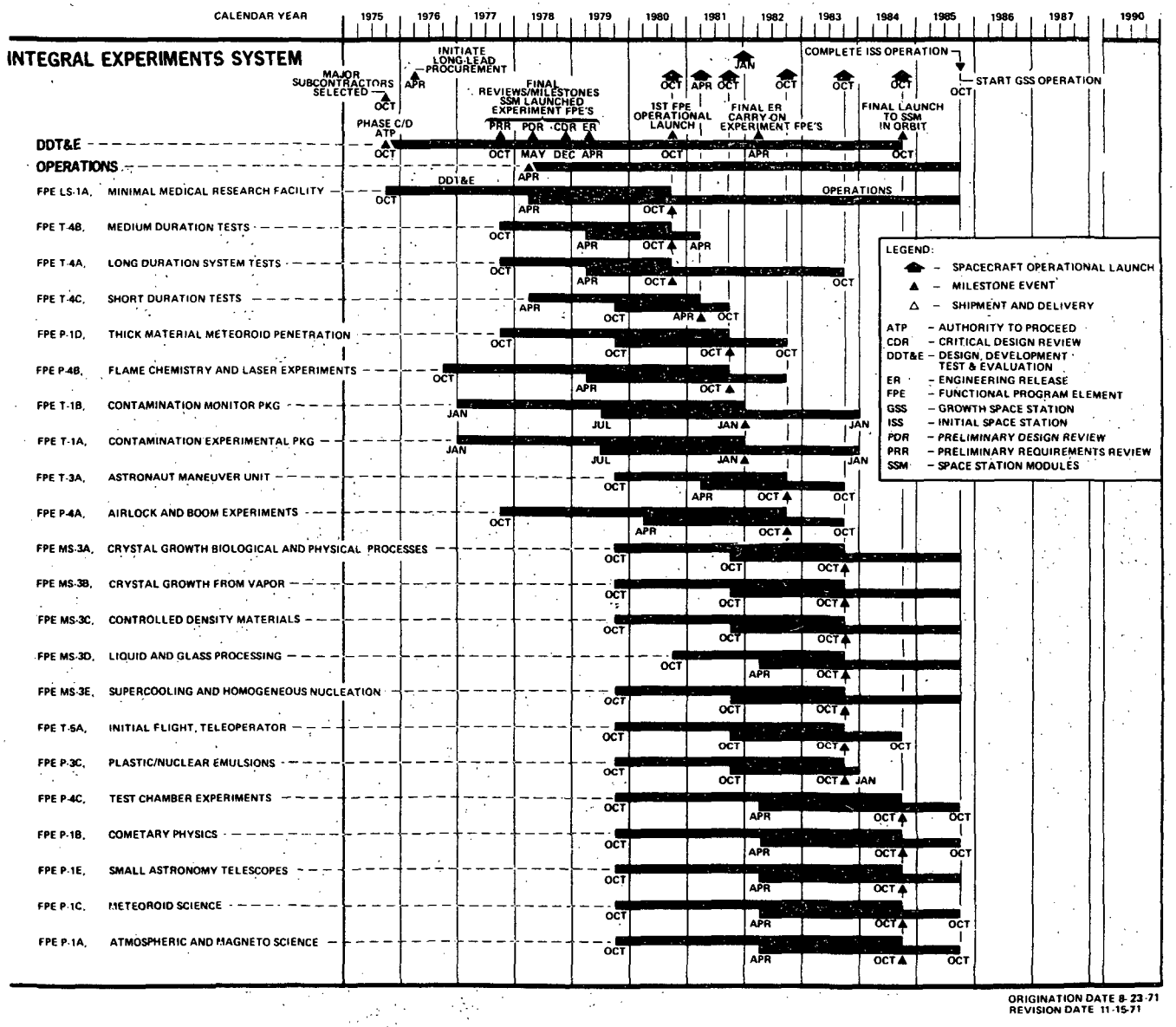


Figure 4-9. Integral Experiments System Schedule (ISS Only)

4.4 EXPERIMENT INTEGRATION—ISS ONLY (WBS2X052)

4.4.1 Summary

Experiment integration consists of those tasks and onboard experiment support equipment required to integrate the integral experiments with the Space Station Modules. It includes experiments launched with the Station and those experiments planned for separate launch during the operational phase

Definition

The task definition of this WBS Box is contained in Appendix A.

Cost Assumptions, Ground Rules and Rationale

None in addition to those in Section 2.1.2.

4.4.2 Cost

4.4.2.1 Cost Methodology

The estimated costs have been developed from summations of cost estimates at subordinate levels. The subordinate cost estimates were developed at one or more levels below that being reported. The costs reported at this level include the cost of integrating the elements at the subordinate levels.

4.4.2.2 Cost Estimate

The total cost is estimated to be $96 millions, all of which is DDT&E. It is estimated that the DDT&E effort will begin 54 months prior to the milestone launch date of October 1980, and will require 96 months for completion.

4.4.2.3 Funding Distribution

Figure 4-10 is a Summary Chart which highlights the relationships of the cost estimates to Technical Characteristics and Schedules. It also presents an overview of the funding allocations, both yearly and cumulatively by Government Fiscal Year (Mid-Year Plot). DDT&E funding has been spread using a 50 percent Spread Function.

EXPERIMENT INTEGRATION (ISS) TECHNICAL DESCRIPTION WBS 2X052

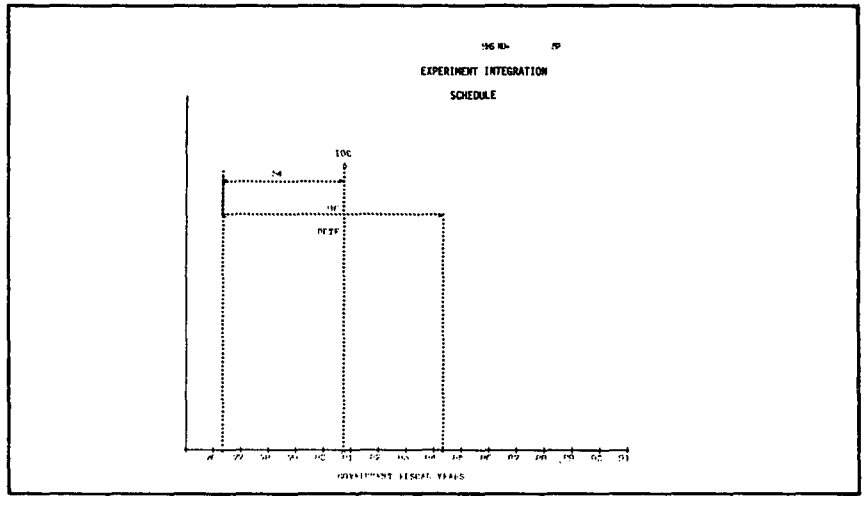
PROVIDES ALL FUNCTIONS REQUIRED FOR INTEGRATION OF INTEGRAL EXPERIMENTS INTO THE GFL MODULE OF THE SPACE STATION MODULES SYSTEM, INCLUDING:

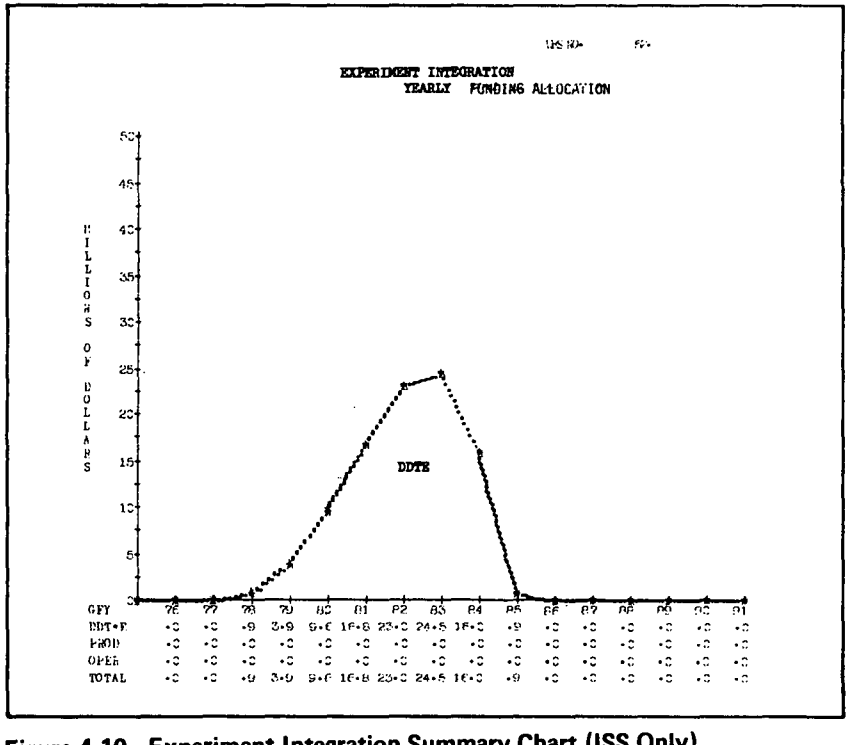
Design Integration of interfaces, procedures and software

Experiment Support Hardware (Unique to Integration Task and Individual PPE) for adapting experiments to the Space Station, including development and production

Test Integration, as required using the FIT, between Experiment "N's) and Space Station, and between Experiment GSE and Space Station

Production Integration of Flight Experiments





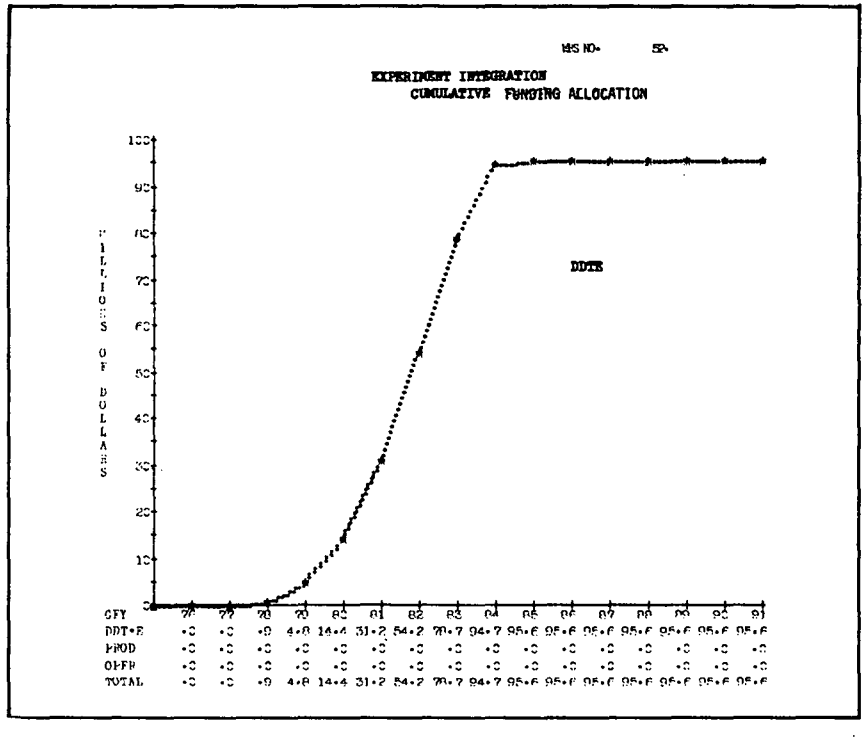


Figure 4-10. Experiment Integration Summary Chart (ISS Only)

4.4.3 Schedule

Major milestones and key events coincide with like events of the Integral Experiment System. Design, Development, Test and Engineering (DDT&E) includes all effort for experiment integration initial engineering, test operations, and production planning. Operations tasks cover the production manufacturing of onboard experiment support equipment and the installation and checkout of onboard experiments and support equipment included in the vehicle at launch. Integration tasks continue after launch of Space Station Modules utilizing the Flight Integration Tool for installation and checkout verification of carry-on experiments (see Figure 4-11).

Design engineering is initiated for the first FPE at Experiment Integration ATP, October 1976. The selection of major subcontractors and the initiation of long lead procurement occur at October 1976 and April 1977, respectively, to ensure coordination of requirements and establish material availability. Development, (including experiment support equipment) development and qualification testing, and production planning and tooling continue to launch of the final FPE in October 1984. Operations are initiated with the first FPE requirement in October 1978, 2 years before first operational launch, and continue to the final FPE launch to orbit in October 1984.

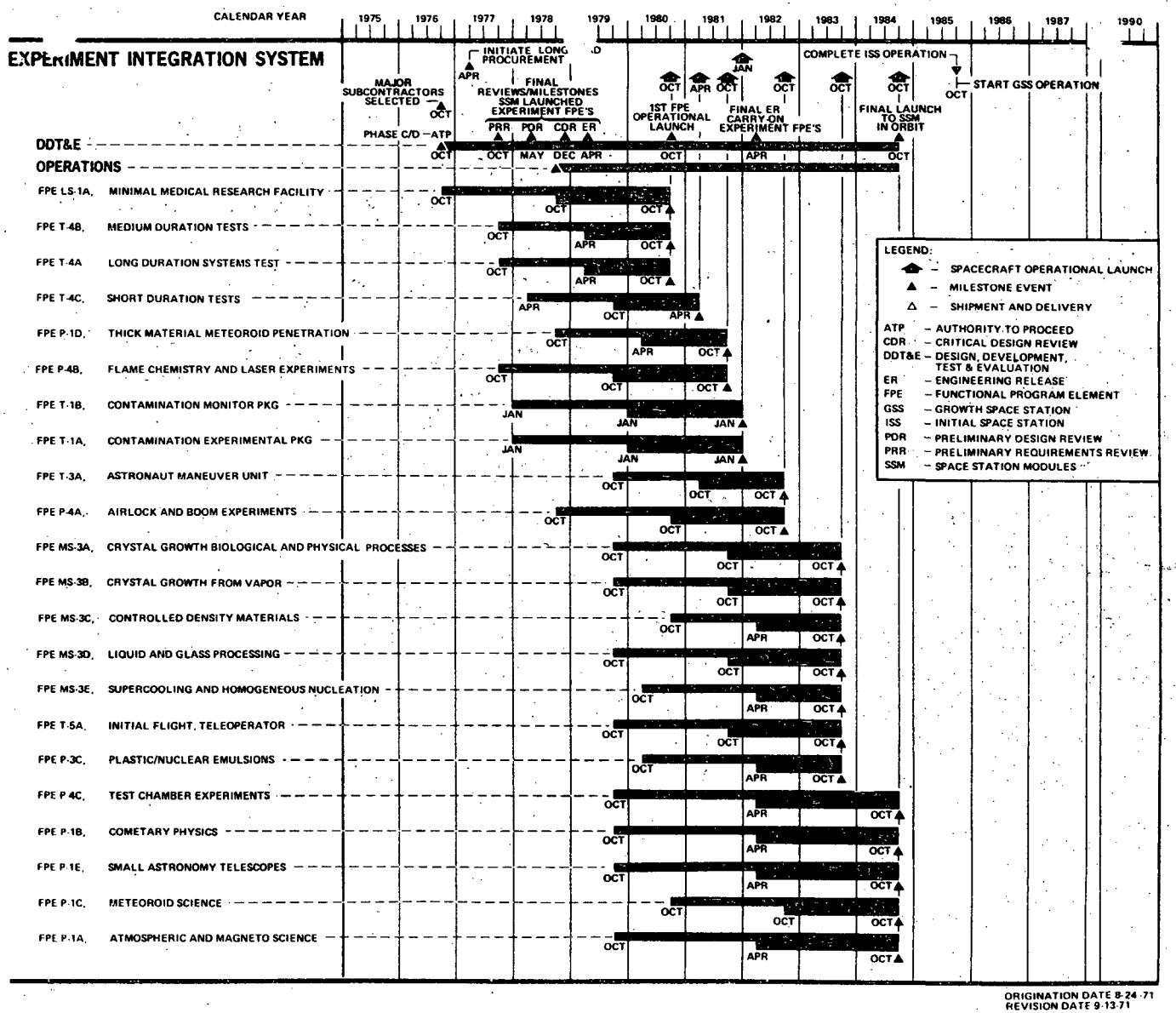


Figure 4-11. Experiment Integration System Schedule (ISS Only)

4.5 GSE—ISS ONLY (WBS 2X369)

4.5.1 Summary

4.5.1.1 GSE

The Ground Support Equipment System consists of the Space Station Modules, Logistics Modules, Experiments, Test Articles, Launch Operations and Flight Operations GSE. Within these groups is the integrated checkout, servicing, access, handling, electrical and transportation equipment.

Definition

The task definition of this WBS Box is contained in Appendix A.

Cost Assumptions, Ground Rules and Rationale

None in addition to those in Section 2.1.2.

4.5.1.1.1 Space Station Modules GSE (WBS 2X269)

Includes:

- Integrated Checkout Equipment
- Electrical GSE
- Servicing Equipment
- Access Equipment
- Handling and Protection Equipment
- Transportation Equipment
- Miscellaneous Equipment

4.5.1.1.2 Logistic Module GSE (WBS 2X261)

Includes GSE for spares.

4.5.1.1.3 Experiment GSE (WBS 2X309)

Includes a GSE allocation computed as a percentage of Blue Book FPE Costs. (See subsection 4.3.1, Table 4-4.)

4.5.1.1.4 Test Article GSE (WBS 2X299)

No Test Article GSE is required. The FM will use Space Station Modules Development GSE. The FIT will use Space Station Modules Flight Article GSE.

4.5.1.1.5 Launch Operations GSE (WBS 2X279)

Includes:

- Propellant and Cleaning Fluid Transfer Equipment
- Launch Electrical Distribution Group
- Launch Umbilical Kit

4.5.1.1.6 Flight Operations GSE (WBS 2X289)

Includes:

- Mission Operations Support Equipment
- Flight Operations Display and Control Unit
- Mission Analysis/Planning Display and Control Group
- Logistics Support Display and Control Group
- Experiment Support Display and Control Group

4.5.2 Costs

Cost Methodology

The estimated costs have been developed from summations of cost estimates at subordinate levels. The subordinate cost estimates were developed at one or more levels below that being reported. The costs reported at this level include the cost of integrating the elements at the subordinate levels.

4.5.2.1 GSE

Cost Estimate

The total cost is estimated to be $93 millions, all of which is DDT&E.

It is estimated that the DDT&E effort will begin 60 months prior to the milestone launch date of October 1980, and will require 96 months for completion.

Funding Distribution

Figure 4-12 is a Summary Chart which highlights the relationships of the cost estimates to technical characteristics and schedules. It also presents an overview of the funding allocations, both yearly and cumulatively by Government Fiscal Year (Mid-Year Plot). DDT&E funding has been spread using a 40 percent spread function.

4.5.2.1.1 Space Station Module GSE (WBS 2X269)

Cost Estimate

The total cost is estimated to be $27 millions, all of which is DDT&E.

It is estimated that the DDT&E effort will begin 60 months prior to the milestone launch date of October 1980, and will require 52 months for completion.

4.5.2.1.2 Logistic Module GSE (WBS 2X261)

Cost Estimate

The total cost is estimated to be $14 millions, all of which is DDT&E.

It is estimated that the DDT&E effort will begin 58 months prior to the milestone launch date of October 1980, and will require 56 months for completion.

4.5.2.1.3 Experiment GSE (WBS 2X309)

Cost Estimate

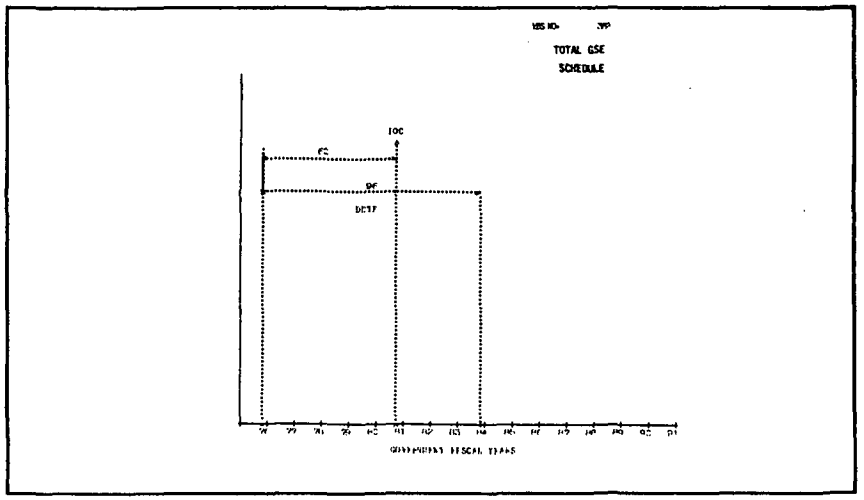
The total cost is estimated to be $37 millions, all of which is DDT&E.

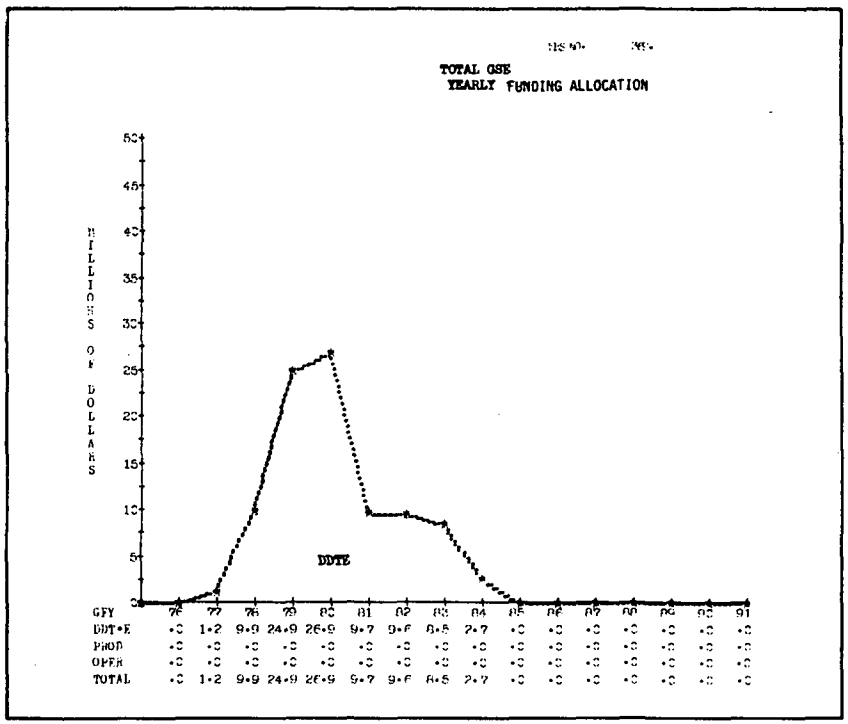
It is estimated that the DDT&E effort will begin 60 months prior to the milestone launch date of October 1980, and will require 96 months for completion.

GSE (ISS ONLY) TECHNICAL DESCRIPTION WBS 2K369

ENCOMPASSES ALL GSE REQUIRED FOR THE SPACE STATION PROJECT, INCLUDING:

- SPACE STATION MODULES GSE
- LOGISTICS MODULE GSE
- INTEGRAL EXPERIMENTS GSE
- TEST ARTICLES GSE
- LAUNCH OPERATIONS GSE
- FLIGHT OPERATIONS GSE





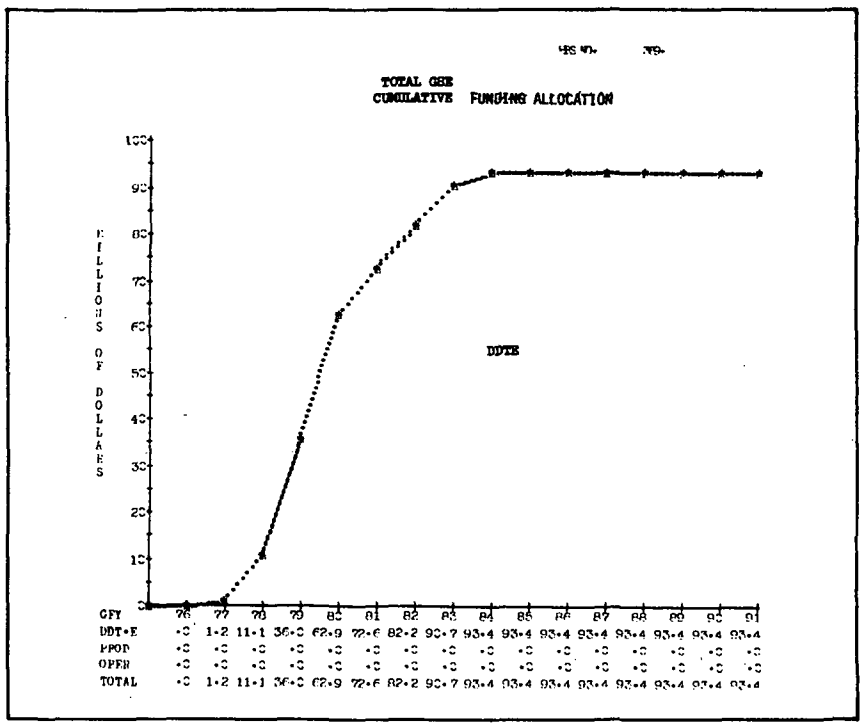


Figure 4-12. GSE Summary Chart (ISS Only)

4.5.2.1.4 Test Article GSE (WBS 2X299)

Cost Estimate

The total cost is zero, since no Test Article GSE is required.

4.5.2.1.5 Launch Operations GSE (WBS 2X279)

Cost Estimate

The total cost is estimated to be $1 million, all of which is DDT&E.

It is estimated that the DDT&E effort will begin 59 months prior to the milestone launch date of October 1980, and will require 48 months for completion.

4.5.2.1.6 Flight Operations GSE (WBS 2X289)

Cost Estimate

The total cost is estimated to be $14 millions, all of which is DDT&E.

It is estimated that the DDT&E effort will begin 56 months prior to the milestone launch date of October 1980, and will require 48 months for completion.

4.5.3 Schedule

Shown on the GSE System Schedule is the effort required to design, develop, produce and deliver the equipment. Operations using the GSE are covered on other schedules. All GSE activities are considered as DDT&E (non-recurring). Initial design ATP is in April 1976, and Development begins 10 months later in February 1977, to support the Functional Model (FM) GSE requirements. Development effort is complete in April 1984, with the delivery of the GSE for the final experiment FPE checkout (see Figure 4-13).

One set of Space Station Modules GSE is used at the factory for checkout and acceptance test. That portion of the equipment needed for transportation and pre-launch servicing at the launch site is delivered to the site with the

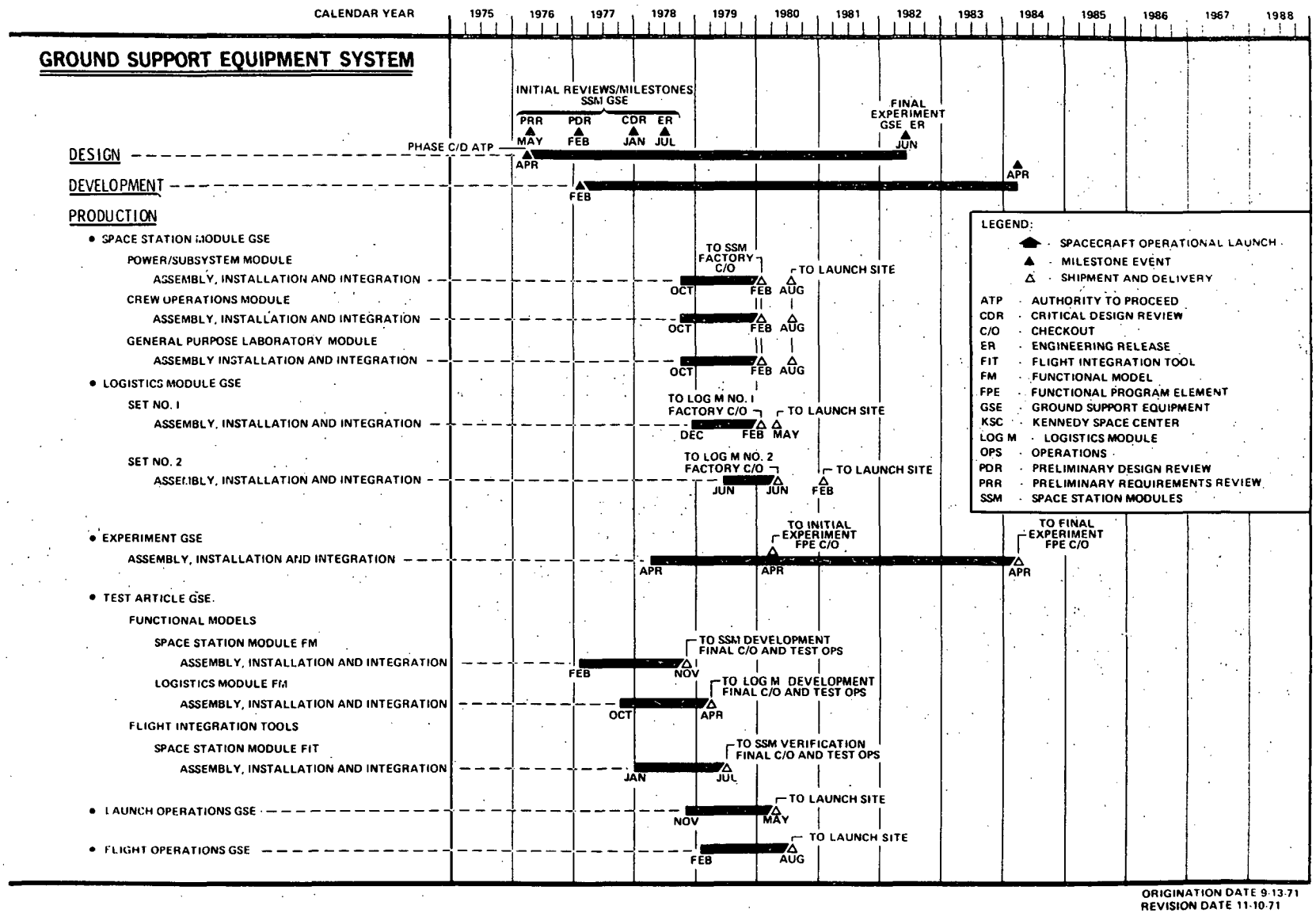


Figure 4-13. Ground Support Equipment System Schedule (ISS Only)

Space Station Modules to be used in conjunction with the Launch Operations GSE.

Two sets of Logistics Module GSE are produced. Set 1 is used to checkout the first LOG M at the factory. It is then delivered to the launch site with LOG M 1. Set 2 is used at the factory to checkout LOG M through 4. It is then delivered to the launch site with LOG M 4 to be used for handling and final checkout of the LOG M's.

Experiment GSE includes the checkout, handling, shipping and servicing equipment required to support experiments to be integrated into the Space Station Modules. One set of peculiar GSE is required for each FPE except that items provided for one experiment will be utilized on others where commonality exists. Assembly of Experiment GSE begins April 1978 with assembly of the first FPE set. The requirements are complete with the delivery of the final experiment FPE GSE set in April 1984 six months before the final FPE launch of the Initial Space Station (ISS) phase.

Test Article GSE is that equipment required for the Functional Model and Flight Integration Tool in support of interface development and checkout and launch procedures. Supporting service and access equipment is also included. Equipment assembly is initiated with the Functional Model GSE for Space Station Modules development and is complete with delivery of the equipment required for start of SSM qualification final checkout and test operations in July 1979. All of this equipment is presently supplied from the SSM GSE.

Launch and Flight Operations GSE is delivered to the launch site in May and August 1980 respectively. The equipment consists of modified or new equipment required for support of the Space Station Modules, Logistics Modules or integrated experiments during preparation for launch, and flight operations. This equipment is that which is not already included in GSE required for manufacture, handling and checkout or specialized equipment for use where existing capability does not exist.

4.6 TEST ARTICLE "N"—ISS ONLY (WBS 2X081, 2X082)

4.6.1 Summary

The test article system consists of Space Station Modules test articles; a Functional Model (FM) and a Flight Integration Tool (FIT), and the Logistics Modules test article; an FM.

Definition

The task definition of this WBS Box is contained in Appendix A.

Cost Assumptions, Ground Rules and Rationale

None in addition to those in Section 2.1.2.

4.6.1.1 Test Articles

Test Article Hardware requirements for each subsystem are tabulated in Table 4-5 for the Functional Model and the Flight Integration Tool. Test Article "N" Costs also include the design associated with the Test Articles specifically.

4.6.1.2 Functional Models (WBS 2X082)

Reference the definition in Appendix A.

4.6.1.3 Flight Integration Tool (FIT) (WBS 2X081)

Table 4-6 tabulates the Spares Estimate for the FIT as a percent equivalent of each subsystem. The cost of the spares is included in the Operations Cost of the FIT.

4.6.2 Costs

4.6.2.1 Test Articles

Cost Methodology

The estimated costs have been developed from summations of cost estimates at subordinate levels. The subordinate cost estimates were developed at one or more levels below that being reported. The costs reported at this level include the cost of integrating the elements at the subordinate levels.

Table 4-5

SPACE STATION MODULES TEST ARTICLES
EQUIVALENT SUBSYSTEMS QUANTITY
(Shipsets)[4]

WBS	Subsystem	Test Article Requirements (See Notes 1 and 2) FM	Add to FM	FIT	Add to FIT	Test (3) Article "N" Manufacturing Requirements
8x24	Electrical Power	0.7	0.2	0.8	0.2	0.4
8x50	EC/LS	0.2	0	1.0	0.8	0.8
8x59	Crew Habitability and Protection	0.1	0	0.9	0.7	0.7
8x23	Propulsion/Reaction Control	0.2	0	0.9	0.6	0.6
8x47	Data Management	0.9	0.7	1.0	0.8	1.5
8x56	Stabilization and Attitude Control	0.4	0	0.5	0.2	0.2
8x46	Guidance and Navigation	0.6	0.1	0.4	0	0.1
8x07	Communications	0.6	0.2	0.5	0.2	0.4
8x57	Onboard Checkout and Fault Isolation	0.8	0.6	1.0	0.9	1.5
8x02	Structural/Mechanical	0	0	0.9	0.1	0.1
8x39	Experiment Support Equipment	0.6	0.2	1.0	0.5	0.7

Notes:

1. Subsystem development test hardware satisfies functional model requirements except for additions noted.
2. Subsystem Qualification Test hardware satisfies FIT Requirements except for additions noted.
3. Test Article Mfg is any additional subsystem equipment not furnished from test hardware. Manufacturing tasks are in Test Article "N" WBS.
4. Shipset is Space Station Modules equivalent (three modules worth).

Table 4-6

TEST ARTICLE "N" FLIGHT INTEGRATION TOOL
SPARES ESTIMATE

Subsystem	Percent of Subsystem Installed	Spares as a Percent of Total Subsystem
Structural/Mechanical	70	0.30
EC/LS	40	60.0
Communications	80	80.4
Propulsion/RCS	40	6.84
Electrical Power	60	41.0
Guidance and Navigation	60	28.06
Data Management	100	100.5
Stabilization and Attitude Control	40	18.44
Onboard Checkout and Fault Isolation	90	67.5
Crew Habitability	100	41.0
Experiment Support Equipment	100	61.0

4.6.2.1.1 Cost Estimate

The total cost is estimated to be $216 millions, as follows:

DDT&E—It is estimated that the DDT&E effort will cost $161 millions, will begin 48 months prior to the milestone launch date of October 1980, and will require 27 months for completion.

Operations—It is estimated that the Operation effort will cost $55 millions, will begin 36 months prior to the milestone launch date of October 1980, and will continue for 44 months.

4.6.2.1.2 Funding Distribution

Figure 4-14 is a Summary Chart which highlights the relationships of the cost estimates to technical characteristics and schedules. It also presents an overview of the funding allocations, both yearly and cumulatively by Government Fiscal Year (Mid-Year Plot). DDT&E funding has been spread using 55/65 percent Spread Functions, and operations funding is based on a composite spread function.

4.6.2.2 Functional Model (WBS 2X082)

4.6.2.2.1 Cost Estimate

The total cost is estimated to be $43 millions, all of which is DDT&E.

It is estimated that the DDT&E effort will begin 47 months prior to the milestone launch date of October 1980, and will require 18 months for completion.

4.6.2.3 Flight Integration Tool (WBS 2X081)

4.6.2.3.1 Cost Estimate

The total cost is estimated to be $173 millions, as follows:

DDT&E—It is estimated that the DDT&E effort will cost $118 millions, will begin 48 months prior to the milestone launch date of October 1980, and will require 27 months for completion.

Operations—It is estimated that the Operation effort will cost $55 millions, will begin 36 months prior to the milestone launch date of October 1980, and will continue for 44 months.

4.6.3 Schedule

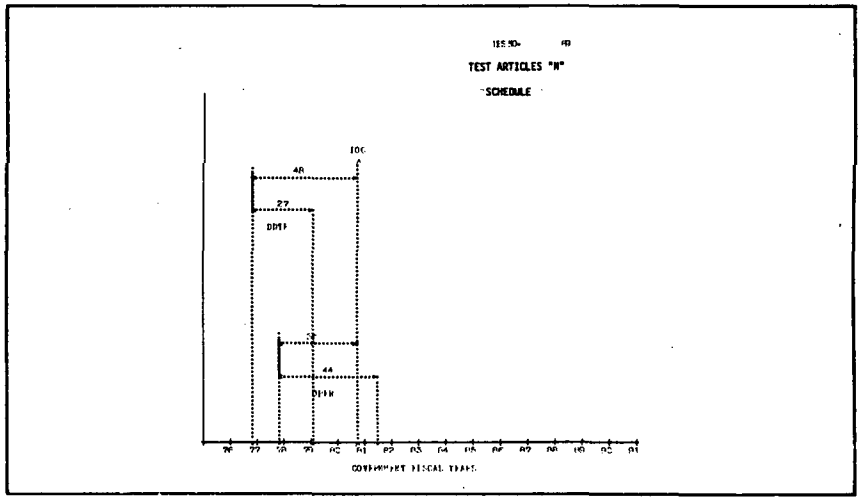
The Test Article System consists of Space Station Modules test articles; a Functional Model (FM) and a Flight Integration Tool (FIT), and the Logistics Modules test article; an FM (see Figure 4-15).

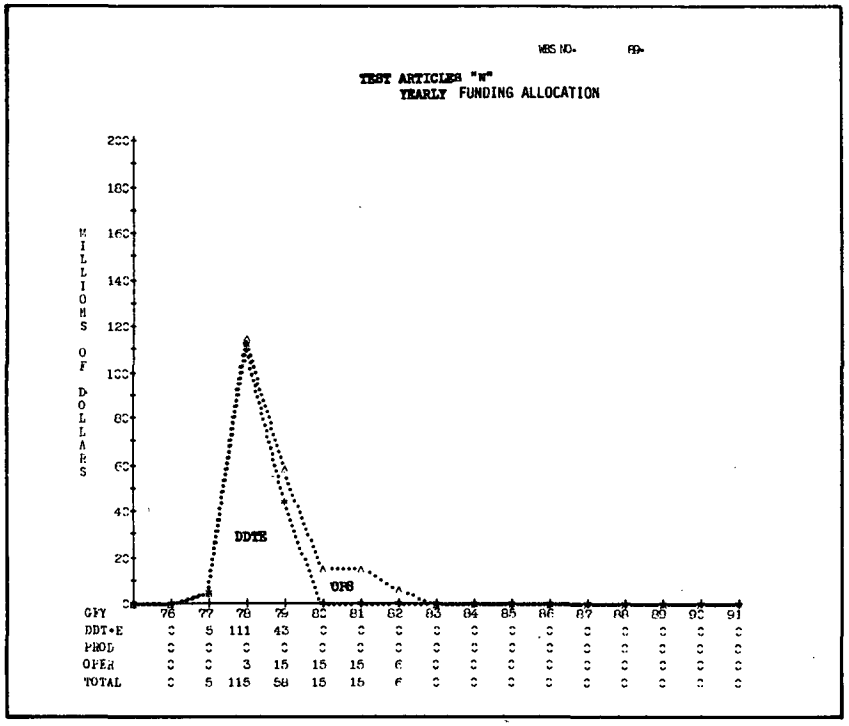
TEST ARTICLES "N" (ISS) TECHNICAL DESCRIPTION WBS 2X31, 2X32

ENCOMPASSES ALL CONTRACTOR HARDWARE COSTS ATTRIBUTABLE TO PROJECT/SYSTEM LEVEL TEST ARTICLES *REQUIRED FOR THE SPACE STATION PROJECT, INCLUDING:*

FUNCTIONAL MODEL (FM)
- A "PIPE RACK" WITH OPERABLE SUBSYSTEMS (USES HARDWARE FROM SUBSYSTEM DEVELOPMENT) FOR FUNCTIONAL SUBSYSTEM INTEGRATION TESTS AND SUBSYSTEM MAINTAINABILITY.
- CONSISTS OF FUNCTIONAL ELECTRONIC SUBSYSTEMS WITH INTERFACING ELEMENTS FROM OTHER SUBSYSTEMS, PLUS SOFTWARE AND GENERAL NON-DEDICATED COMPUTING CAPABILITY
- TESTS - USED FOR INITIAL SOFTWARE DEVELOPMENT TEST

FLIGHT INTEGRATION TOOL (FIT)
- FLIGHT CONFIGURATION SPACE STATION MODULES, INCLUDING FLIGHT QUALIFICATION HARDWARE, USED FOR HARDWARE/SOFTWARE VERIFICATION AND CONFIGURATION CONTROL
- AFTER LAUNCH OF SPACE STATION MODULES, FIT WILL BE USED FOR INTEGRATION OF EXPERIMENTS AND SUBSYSTEM MODIFICATIONS TO BE INSTALLED IN ORBIT





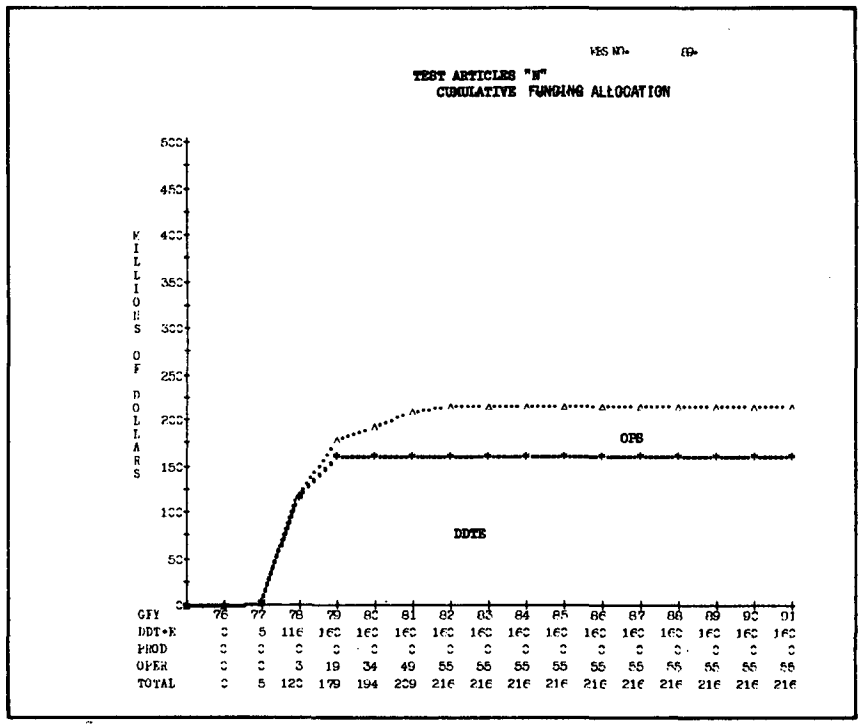


Figure 4-14. Test Articles "N" Summary Chart (ISS Only)

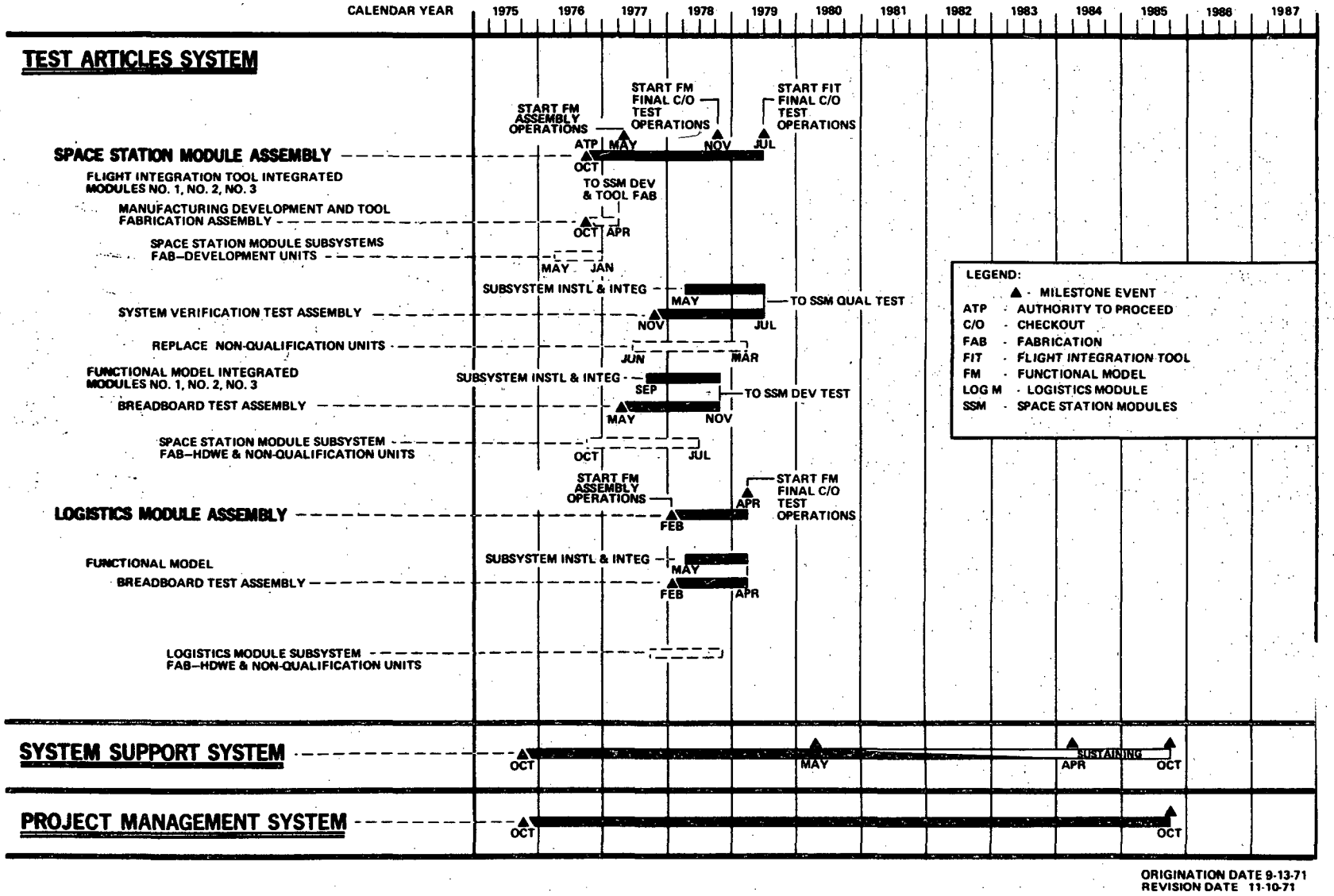


Figure 4-15. Test Articles/System Support/Project Management System Schedule (ISS Only)

The FM is a development tool that will functionally represent an operational vehicle, but in rack and panel type assembly. The major objective of the FM is to perform interface development testing among AVE subsystems and between AVE subsystem and GSE in support of system-level integration development testing (primarily for electrical continuity checks).

The FIT is a manufacturing tool to provide a check of the physical compatibility of subsystems design configurations. It will be produced using facilities where the operational vehicle will be produced. It will be developed in a production-like manner, including acceptance tests. The FIT will be used for system integration testing, software development, and operating procedure development. Subsequent to integration and checkout completion it is used for installation/integration of experiments for orbit installations. (All Space Station Modules and Logistics Module test operations using the FM and FIT are performed by the SSM and LOG M systems).

Test Article System activity is initiated in May 1977 with assembly of the SSM FM breadboard assembly. Subsystem installation and integration begins in September 1977, fourteen months before the start of SSM development test. The Test Article System is complete when the SSM FIT is complete and ready to start final checkout and test operations in July 1979.

The System Support System includes initial system engineering, engineering integration, all sustaining engineering and production checkout engineering (see Appendix A). System support is initiated at program Phase C/D ATP and continues to the end of the ISS phase, October 1985. DDT&E (non-recurring) maximum effort continues until the Space Station Modules FACI is achieved in May 1980. From that point the DDT&E system support is a decreasing effort until it is reduced to zero as the last ISS experiment FPE FACI is achieved in April 1984. Sustaining engineering begins at completion of SSM FACI in May 1980 and continues to the completion of the ISS phase in support of experiment integration and operations.

The Project Management System is comprised of the management effort covering all of the Space Station Project elements, including the integral

experiment items. Functions within these project elements are defined in Appendix A.

Project Management is a continuing effort beginning with program phase C/D ATP, achieving maximum activity in the three years before SSM operational launch, and decreasing during operations to complete the ISS phase in October 1985. Additional effort takes place during GSS which overlaps ISS by 5 years in the program management area.

4.7 LAUNCH OPERATIONS—ISS ONLY (WBS 2X491)

4.7.1 Summary

The Launch Operations System contain all launch operations associated with the Space Station Project. Under Launch Operations is the site activation prior to Space Station delivery, all preparation and conduct of launch, post-launch operations and inplant contractor support of launch operations.

Definition

The task definition of this WBS Box is contained in Appendix A.

Cost Assumptions, Ground Rules, and Rationale

None in addition to those in Section 2.1.2.

4.7.2 Cost

4.7.2.1 Cost Methodology

The estimated costs have been developed from summations of cost estimates at subordinate levels. The subordinate cost estimates were developed at one or more levels below that being reported. The costs reported at this level include the cost of integrating the elements at the subordinate levels.

4.7.2.2 Cost Estimate

The total cost is estimated to be $54 millions, all of which is Operations Cost.

Operations—It is estimated that the Operation effort will cost $54 millions, will begin 45 months prior to the milestone launch date of October 1980, and will continue for 99 months.

4.7.2.3 Funding Distribution

Figure 4-16 is a Summary Chart which highlights the relationships of the cost estimates to Technical Characteristics and Schedules. It also presents an overview of the funding allocations, both yearly and cumulatively by

LAUNCH OPERATIONS (ISS) TECHNICAL DESCRIPTION WBS 2X491

ENCOMPASSES ALL CONTRACTOR COSTS ATTRIBUTABLE TO LAUNCH OPERATIONS ASSOCIATED WITH THE SPACE STATION PROJECT, INCLUDING:

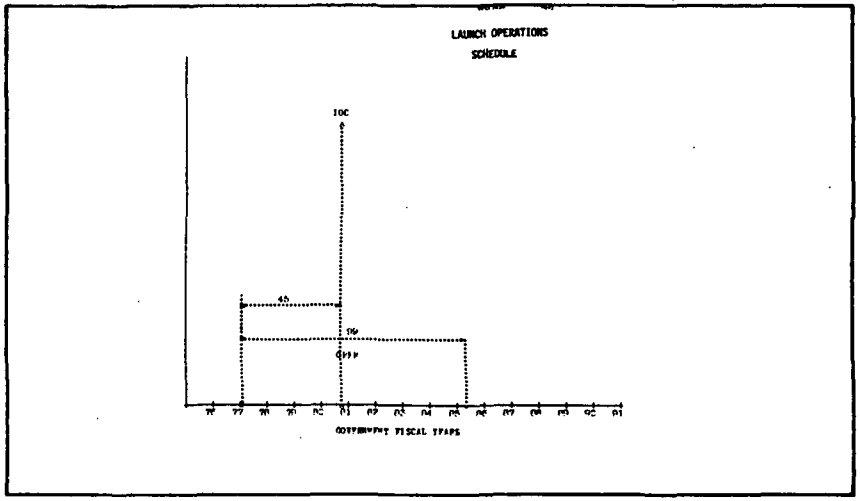
SITE ACTIVATION	-	PRIOR TO SPACE STATION DELIVERY TO LAUNCH SITE
LAUNCH GSE	-	INSTALLATION AND MAINTENANCE
JOINING TO SHUTTLE	-	INTERFACE CHECK WITH SHUTTLE, TRANSPORTATION TO PAD
PAD CHECKOUT		
COUNTDOWN		
LAUNCH AND ASCENT		
POST-LAUNCH DEACTIVATION		

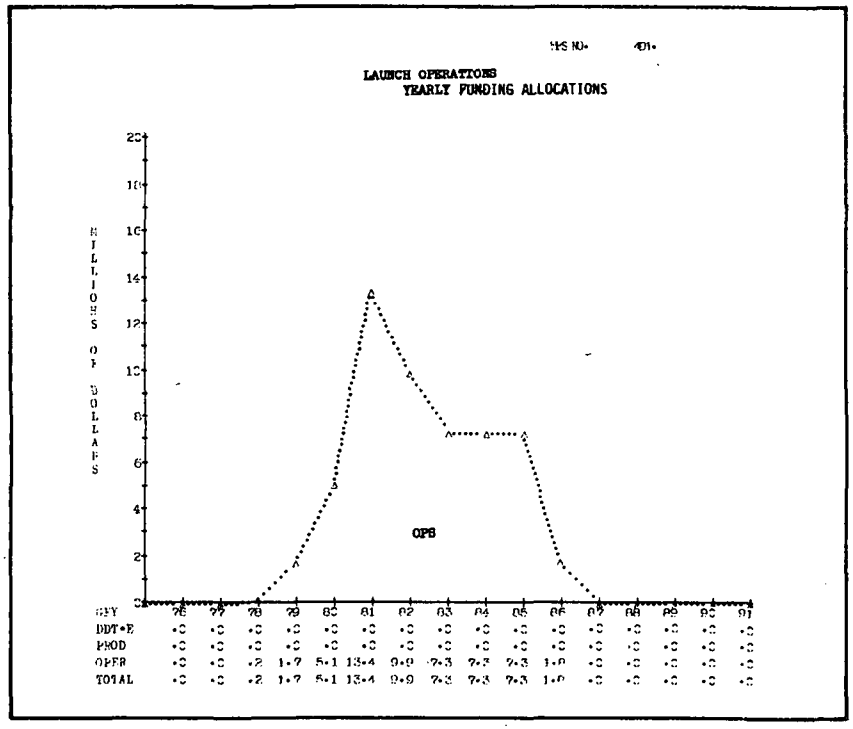
FEATURES:

FACTORY ASSEMBLY AND CHECKOUT PERSONNEL ASSIGNED TO TDY AT LAUNCH SITE - TASK FORCE APPROACH

INCLUDES IN-PLANT CONTRACTOR SUPPORT OF LAUNCH OPERATIONS

EXCLUDES NASA AND SUPPORT AGENCY COSTS, PER NASA DIRECTION





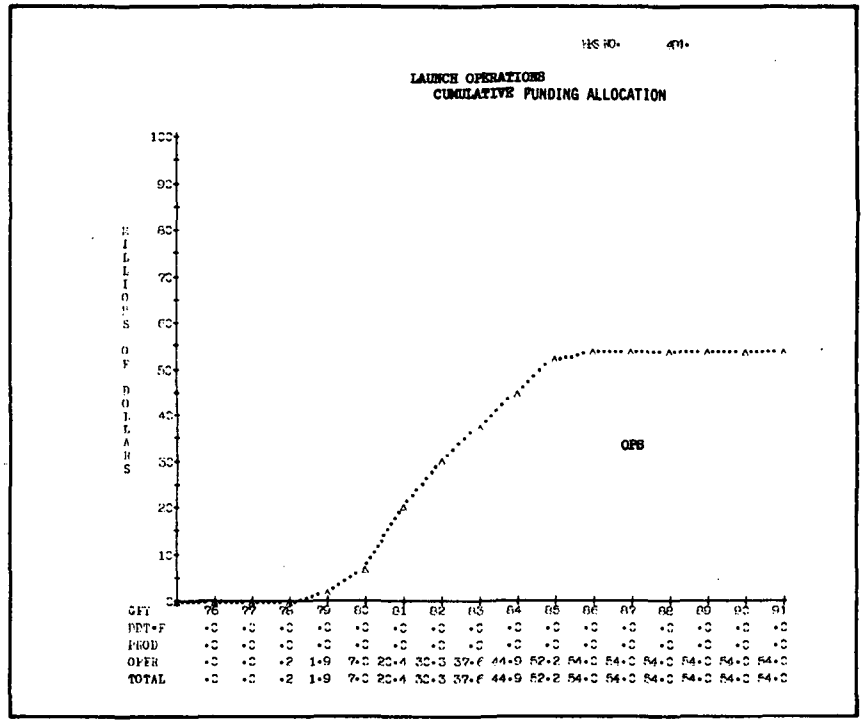


Figure 4-16. Launch Operations Summary Chart (ISS Only)

Government Fiscal Year (Mid-Year Plot). Operations funding is based on a composite spread function.

4.7.3 Schedule

Operations are initiated with the beginning of launch site activation in April 1979, 30 months before first SSM operational launch. First hardware delivery to the launch site is Logistics Module 1 and the corresponding GSE set in May 1980. A total of 4 LOG M's are completed and delivered 3 months apart. LOG M GSE set 2 is used at the factory to checkout modules 2, 3, and 4 delivered to the launch site with LOG M 4 (see Figure 4-17).

In August 1980, the first SSM and associated GSE are delivered to the launch site and experiment operations in support of the integral experiments carried in the Space Station begins. Space Station Modules are delivered to the launch site 1 month apart. Prelaunch checkout is initiated with the arrival of each SSM module at the launch site and continues for a period of two months before launch. The SSM's are launched at 30-day intervals starting in October 1980.

Thirty days after the last SSM is put into orbit the first LOG M is launched and the initial SSM activation crew is carried into orbit onboard the Space Shuttle. The second and third LOG M's are launched 30 days apart accompanied by two Space Station crewmen riding in the Shuttle. Initial Operational Capability (IOC) with 6 men on orbit is accomplished at the completion of the third LOG M launch in March 1981.

A total of 29 LOG M launches and 21 Shuttle-only (Shuttle with 2 Space Station crewmen—no Logistics Module) launches are required to supply the Space Station logistics and to rotate 2 SSM crewmen every 90 days.

A total of 22 FPE's are carried to orbit between August 1980 and October 1984. After the first 3 FPE's are carried to orbit onboard the Space Station all experiment FPE's are carry-on experiments, carried to orbit onboard the Logistics Module, and installed in the SSM's by the SSM crew. Experiment FPE's completed before program termination are

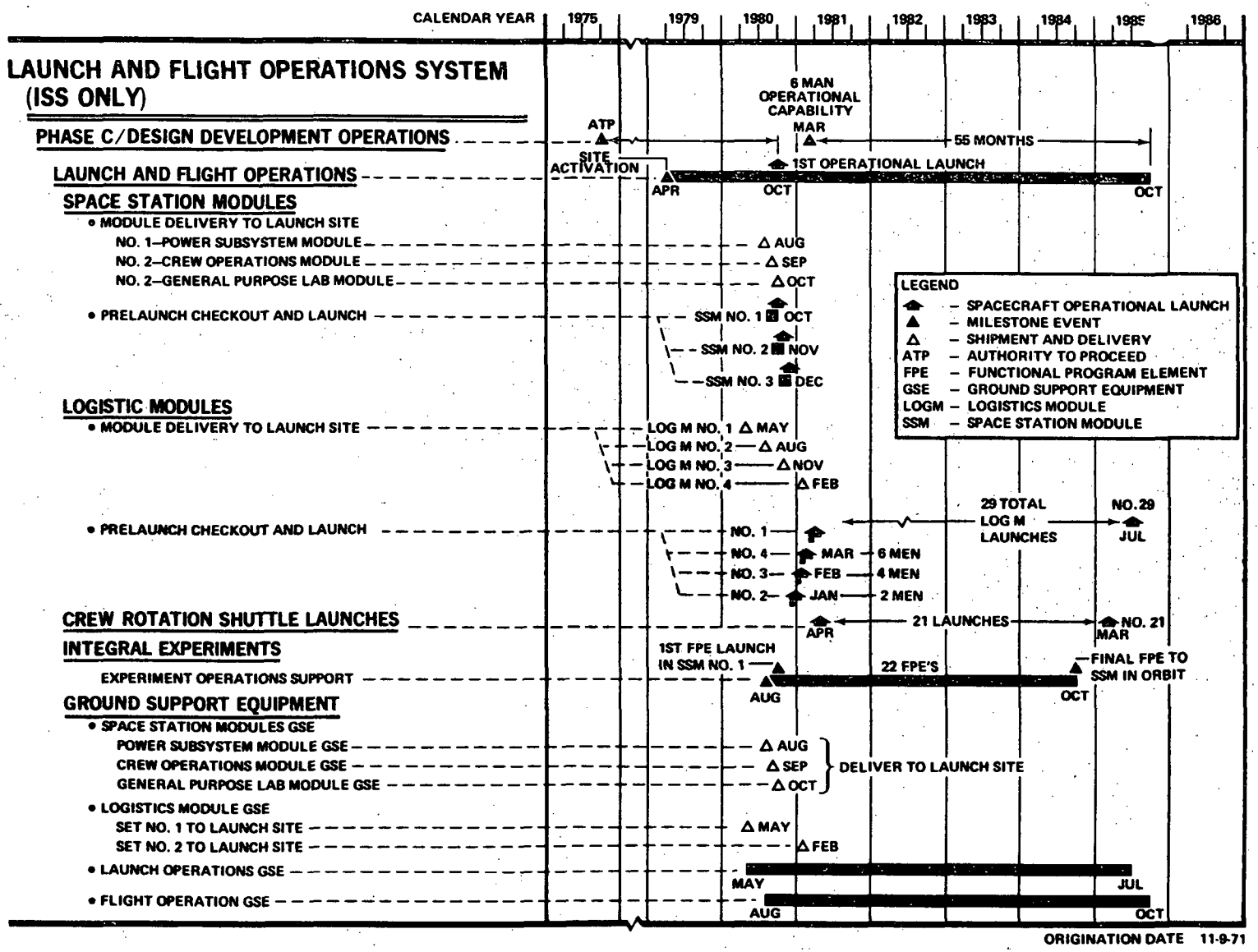


Figure 4-17. Launch and Flight Operations System Schedule (ISS Only)

returned to earth onboard Logistics Modules. Operations continue to support the experiments, logistics, and crew requirements until ISS phase completion in October 1985 and into the GSS phase of the 10 year program. Additional experiment FPE's are carried into orbit during the GSS phase.

4.8 FLIGHT OPERATIONS–ISS ONLY (WBS 2X591)

4.8.1 Summary

Flight Operations are the mission operations and mission operations support functions applicable to the Space Station, integral experiments and attached or free-flying module experiments which are controlled or monitored from the Space Station.

Definition

The task definition of this WBS Box is contained in Appendix A.

Cost Assumptions, Ground Rules and Rationale

None in addition to those in Section 2.1.2.

4.8.2 Cost

4.8.2.1 Cost Methodology

The estimated costs have been developed from summations of cost estimates at subordinate levels. The subordinate cost estimates were developed at one or more levels below that being reported. The costs reported at this level include the cost of integrating the elements at the subordinate levels.

4.8.2.2 Cost Estimate

The total cost is estimated to be $230 millions, all of which is Operations.

It is estimated that the Operation effort will begin 45 months prior to the milestone launch date of October 1980, and will continue for 99 months.

4.8.2.3 Funding Distribution

Figure 4-18 is a Summary Chart which highlights the relationships of the cost estimates to technical characteristics and schedules. It also presents an overview of the funding allocations, both yearly and cumulatively by Government Fiscal Year (Mid-Year Plot). Operations funding is based on a composite spread function.

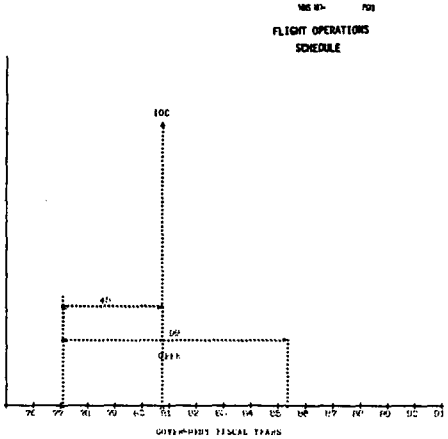
FLIGHT OPERATIONS (ISS) TECHNICAL DESCRIPTION WBS 2X591

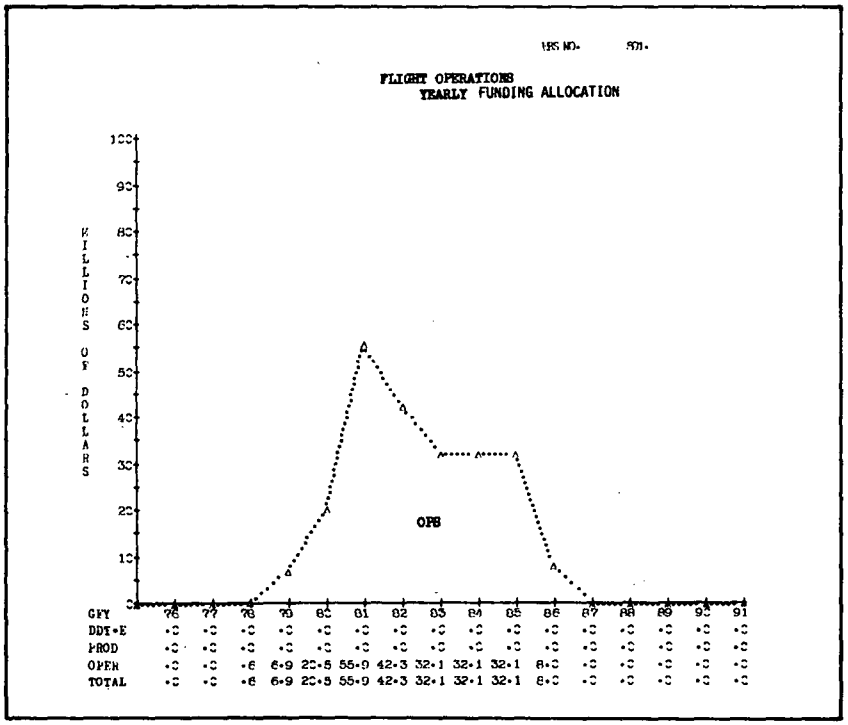
INCLUDES SPACE STATION CONTRACTOR AND EXPERIMENT CONTRACTOR EFFORT REQUIRED FOR:

- MISSION ANALYSIS AND PLANNING
- FLIGHT OPERATIONS SUPPORT
- EXPERIMENT SUPPORT OPERATIONS
- LOGISTICS OPERATIONS SUPPORT

PER NASA DIRECTION, EXCLUDES NASA COSTS FOR:

- MISSION OPERATIONS
- MISSION OPERATIONS SUPPORT
- FLIGHT OPERATIONS SUPPORT (INCLUDING FLIGHT CREW TRAINING; GROUND NETWORK)
- MISSION ANALYSIS AND PLANNING
- EXPERIMENT OPERATIONS SUPPORT
- LOGISTICS OPERATIONS SUPPORT





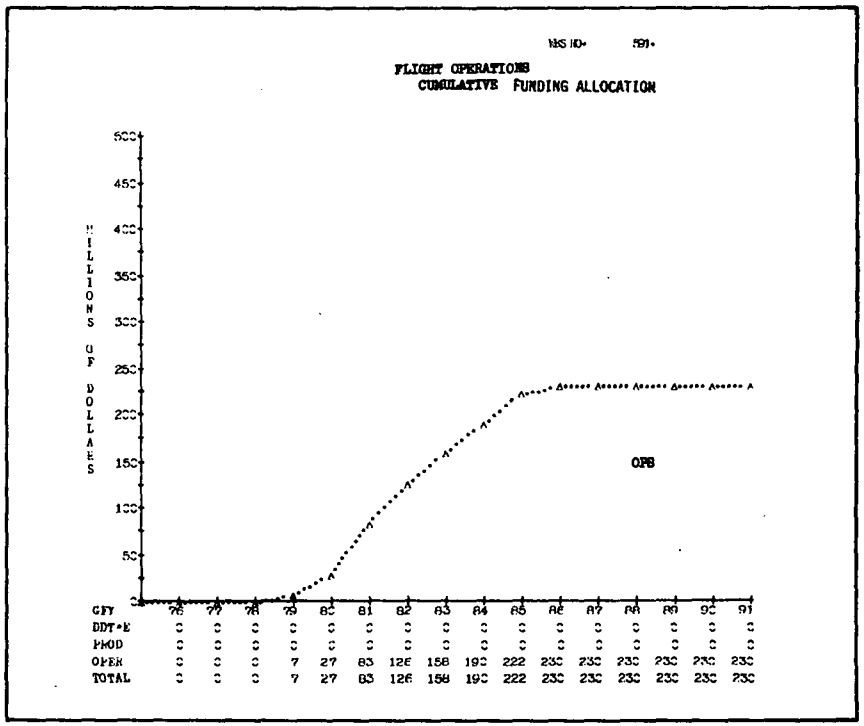


Figure 4-18. Flight Operations Summary Chart (ISS Only)

4.8.3 Schedule

Operations are initiated with the beginning of launch site activation in April 1979, 30 months before first SSM operational launch. First hardware delivery to the launch site is Logistics Module 1 and the corresponding GSE set in May 1980. A total of 4 LOG M's are completed and delivered 3 months apart. LOG M GSE set 2 is used at the factory to checkout modules 2, 3, and 4 delivered to the launch site with LOG M 4.

In August 1980, the first SSM and associated GSE are delivered to the launch site and experiment operations in support of the integral experiments carried in the Space Station begins. Space Station Modules are delivered to the launch site 1 month apart. Prelaunch checkout is initiated with the arrival of each SSM module at the launch site and continues for a period of two months before launch. The SSM's are launched at 30-day intervals starting in October 1980.

Thirty days after the last SSM is put into orbit the first LOG M is launched and the initial SSM activation crew is carried into orbit onboard the Space Shuttle. The second and third LOG M's are launched 30 days apart accompanied by two Space Station crewmen riding in the Shuttle. Initial operational Capability (IOC) with 6 men on orbit is accomplished at the completion of the third LOG M launch in March 1981.

A total of 29 LOG M launches and 21 Shuttle-only (Shuttle with 2 Space Station crewmen—no Logistics Module) launches are required to supply the Space Station logistics and to rotate 2 SSM crewmen every 90 days.

A total of 22 FPE's are carried to orbit between August 1980 and October 1984. After the first 3 FPE's are carried to orbit onboard the Space Station all experiment FPE's are carry-on experiments, carried to orbit onboard the Logistics Module, and installed in the SSM's by the SSM crew. Experiment FPE's completed before program termination are returned to earth onboard Logistics Modules. Operations continue to support the experiments, logistics, and crew requirements until ISS phase completion in October 1985 and into the GSS phase of the 10 year program. Additional experiment FPE's are carried into orbit during the GSS phase.

4.9 FACILITIES – ISS ONLY (WBS 2X124)

4.9.1 Summary

The facilities System consists of launch facilities and mission facilities. Within these groups the following functions are accomplished: architectural and engineering design, construction, and activation of contractor and government facilities.

Definition

The task definition of this WBS Box is contained in Appendix A.

Cost Assumptions, Ground Rules and Rationale

None in addition to those in Section 2.1.2.

4.9.2 Cost

4.9.2.1 Cost Methodology

The estimated costs have been developed from summations of cost estimates at subordinate levels. The subordinate cost estimates were developed at one or more levels below that being reported. The costs reported at this level include the cost of integrating the elements at the subordinate levels.

4.9.2.2 Cost Estimate

The total cost is estimated to be $28 millions, all of which is DDT&E is shown in Table 4-7:

Table 4-7

COST ESTIMATE

WBS	Title	C	DDT&E	Production	Operating	Total
2x12401	Manufacturing Facilities	2	11	0	0	11
2x12402	Test Facilities	2	0	0	0	0
2x12403	Launch Facilities	2	11	0	0	11
2x12404	Mission Control Facilities	2	6	0	0	6
2x12405	MSFN Facilities	2	0	0	0	0
	Facilities	2	28	0	0	28

DDT&E—It is estimated that the DDT&E effort will cost $28 millions, will begin 66 months prior to the milestone launch date of October 1980, and will require 59 months for completion.

4.9.3 Schedule

Facilities system phase C/D ATP begins in August 1978, with the architectural and engineering design of launch facilities modifications required for the Vertical Assembly Low Bays and the Logistics Building. Specifications are completed 2 months later in October 1978, to allow completion of the first engineering release in February of the following year. Launch facilities are complete in May 1980 in time to accept delivery of the first Logistics Module to the launch site. Mission facilities completion in September 1980 is one month before first SSM operational launch (see Figure 4-19).

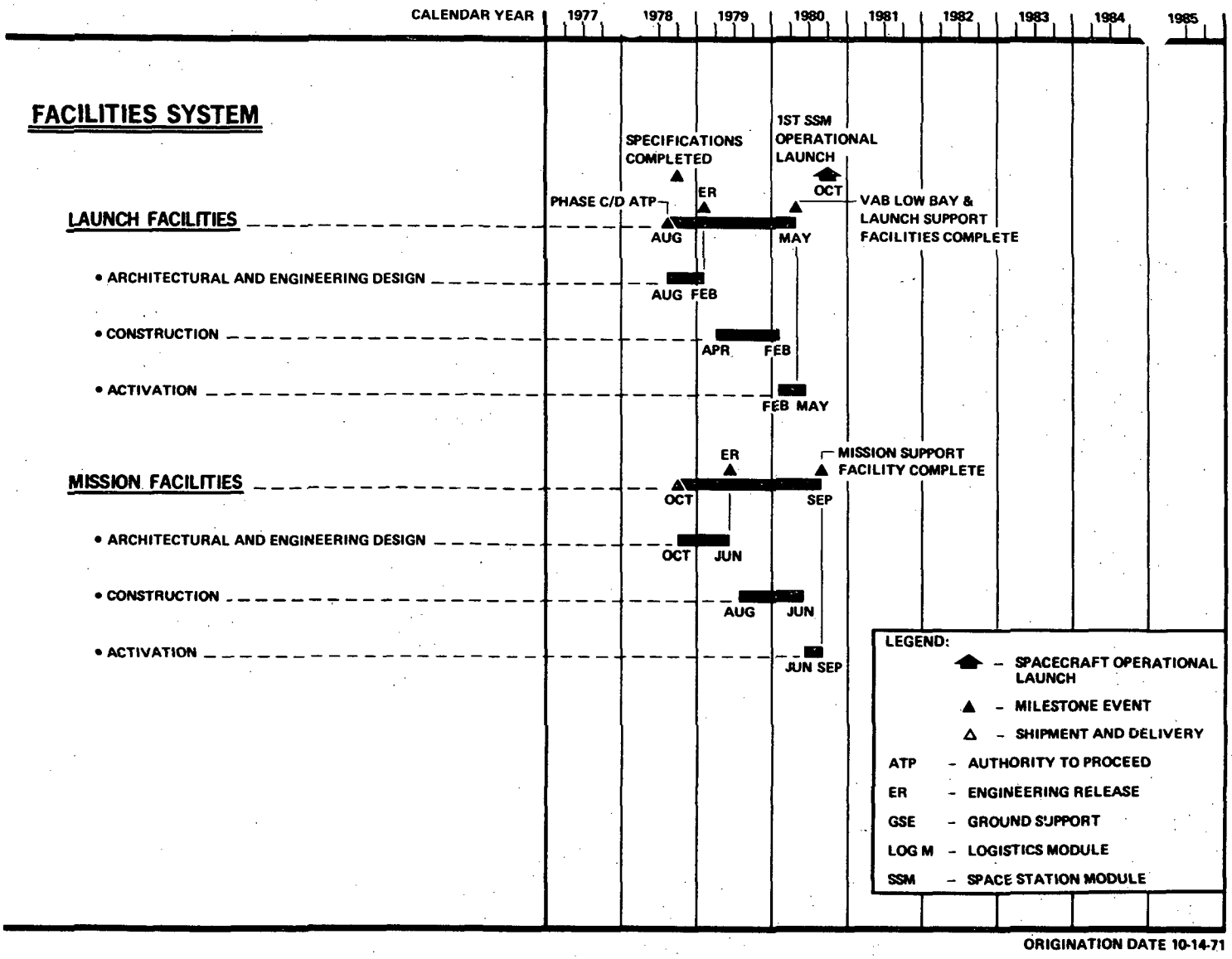


Figure 4-19. Facilities System Schedule (ISS Only)

4.10 SYSTEM SUPPORT – ISS ONLY (WBS 2X064)

4.10.1 Summary

System Support includes initial system engineering, engineering integration, all sustaining engineering and production checkout engineering. System Integration encompasses these functions for the Space Station Modules. System support relates the Space Station Modules to the rest of the Space Station Project systems.

Definition

The task definition of this WBS Box is contained in Appendix A.

Cost Assumptions, Ground Rules and Rationale

None in addition to those in Section 2.1.2.

4.10.2 Cost

4.10.2.1 Cost Methodology

The estimated costs have been developed from summations of cost estimates at subordinate levels. The subordinate cost estimates were developed at one or more levels below that being reported. The costs reported at this level include the cost of integrating the elements at the subordinate levels.

4.10.2.2 Cost Estimate

The total cost is estimated to be $168 millions, as follows:

DDT&E – It is estimated that the DDT&E effort will cost $50 millions, will begin 66 months prior to the milestone launch date of October 1980, and will require 108 months for completion.

Production – It is estimated that the Production effort will cost $30 millions, will begin 36 months prior to the milestone launch date of October 1980, and will require 78 months for completion.

Operations – It is estimated that the Operation effort will cost $88 millions, will begin 24 months prior to the milestone launch date of October 1980, and will continue for 78 months.

4.10.3 Schedule

The System Support System includes initial system engineering, engineering integration, all sustaining engineering and production checkout engineering. (See Appendix A.) System support is initiated at program Phase C/D ATP and continues to the end of the ISS phase, October 1985. DDT&E (non-recurring) maximum effort continues until the Space Station Modules FACI is achieved in May of 1980. From that point the DDT&E system support is a decreasing effort until it is reduced to zero as the last ISS experiment FPE FACI is achieved in April 1984. Sustaining engineering begins at completion of SSM FACI in May 1980 and continues to the completion of the ISS phase in support of experiment integration and operations.

4.11 PROJECT MANAGEMENT—ISS Only (WBS 2X034)

4.11.1 Summary

Project Management includes all contractor effort for management of the Space Station elements, including the integral experiment items. It covers all general management functions, including the management of technical effort.

Definition

The task definition of this WBS Box is contained in Appendix A.

Cost Assumptions, Ground Rules, and Rationale

None in addition to those in Section 2.1.2.

4.11.2 Cost

4.11.2.1 Cost Methodolgy

The estimated costs have been developed from summations of cost estimates at subordinate levels. The subordinate cost estimates were developed at one or more levels below that being reported. The costs reported at this level include the cost of integrating the elements at the subordinate levels.

4.11.2.2 Cost Estimate

The total cost is estimated to be $104 millions, as follows:

DDT&E—It is estimated that the DDT&E effort will cost $57 millions, will begin 66 months prior to the milestone launch date of October 1980, and will require 108 months for completion.

Production—It is estimated that the Production effort will cost $18 millions, will begin 36 months prior to the milestone launch date of October 1980, and will require 78 months for completion.

Operations – It is estimated that the operation effort will cost $29 millions, will begin 24 months prior to the milestone launch date of October 1980, and will continue for 78 months.

4.11.3 Schedule

The Project Management System is comprised of the management effort covering all of the Space Station Project elements, including the integral experiment items. Functions within these project elements are defined in Appendix A.

Project Management is a continuing effort beginning with program phase C/D ATP, achieving maximum activity in the three years before SSM operational launch, and decreasing during operations to complete the ISS phase in October 1985. Additional effort takes place during GSS which overlaps ISS by 5 years in the program management area.

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